

# **Assessment**

## **Forest Plan Revision**

### **Final Forested Terrestrial Vegetation Report**

**Prepared by:**  
Dennis Sandbak  
Silviculturist

**for:**  
Custer Gallatin National Forest

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## Introduction

A draft of this report was released for public review on November 30, 2016 and feedback was requested by January 6, 2017. Changes made to the final report were to add information about the natural range of variation (the reference condition) for tree species presence, tree size class, and tree density class.

This section discusses the forested terrestrial vegetation relevant to the Custer Gallatin National Forest. Vegetation is complex and subject to an array of interacting ecosystem processes. The extent, type, and condition of forested vegetation is dependent upon relatively fixed site capability features on the landscape, such as soils, combined with the influences of system drivers that may impact forest vegetation such as climate, disturbances (for example, insects, wildfire), and human activities (vegetation treatments).

Key concepts related to forest vegetation include resilience, sustainability, adaptive capacity, and ecological integrity. Resilience refers to the ability of an ecosystem and its component parts to absorb or recover from the effects of disturbance through preservation, restoration, or improvement of its essential structures and functions and redundancy of ecological patterns across the landscape (Forest Service Handbook 1909.12 zero code). Sustainability is the capability to meet the needs of the present generation without compromising the ability of future generations to meet their needs (Forest Service Handbook 1909.12 zero code and 36 Code of Federal Regulations 219.19).

Adaptive capacity refers to the ability of ecosystems to respond, cope, or adapt to disturbances and stressors to maintain options for future generations. Adaptive capacity is determined by genetic diversity, biodiversity, and the heterogeneity and integrity of ecosystems occurring as mosaics within broader-scale landscapes (Forest Service Handbook 1909.12 zero code). A landscape mosaic of components or conditions, which may be referred to as spatial heterogeneity, in part through its contributions to resilience may allow adaptation to future environmental change and help to sustain ecosystem services, but humans often rescale or reshape natural heterogeneity (Turner et al. 2012). Spatial heterogeneity is important for sustaining forest regeneration, primary production, carbon storage, natural hazard regulation, insect and pathogen regulation, timber production, and wildlife habitat (ibid).

Ecological integrity refers to the quality or condition of an ecosystem when its dominant ecological characteristics (for example, composition, structure, function, connectivity, and species composition and diversity) occur within the natural range of variation and can withstand and recover from most perturbations imposed by natural environmental dynamics or human influence (Forest Service Handbook 1909.12 zero code). The purpose of assessing for ecosystem integrity is to determine whether ecosystems are functioning normally and are uncompromised. Ecosystems have integrity when their composition, structure, function, and connectivity are operating normally over multiple spatial and temporal scales.

The Forested Vegetation section covers the following topics:

- Current Forest Plan direction relevant to forested vegetation
- Potential forested vegetation types
- Forested vegetation composition, structure, and function (per the identified key ecosystem characteristics)
- Ecosystem diversity

- Forested vegetation drivers (climate change, succession, insects and diseases, and vegetation treatments)

## Process and Methods

Forested ecosystems are complex and dynamic across space and time. Our ability to fully understand and describe processes and inter-relationships of ecosystems is limited. Because of the enormous number of factors that interact with each other in unpredictable ways, we have some data gaps which are noted within the assessment. Some of these gaps may be filled during the forest plan revision process and will be updated. Within this analysis there are tables and figures that display numbers and percentages. In some cases these values have been rounded, the actual values may be slightly larger or smaller. All data derived for these are found in the project record.

## Key Forested Terrestrial Vegetation Characteristics

An ecosystem is defined as a spatially explicit, relatively homogeneous unit of the earth that includes all interacting organisms and elements of the abiotic environment within its boundaries (FSH 1909.12 zero code). Ecosystem integrity is the condition where natural ecological composition, structure, and processes are essentially intact and self-sustaining. This indicates that the ecosystem is able to evolve naturally with its capacity for self-renewal and biodiversity maintained. Ecosystems are described in terms of structure, composition, function, and connectivity (36 Code of Federal Regulations 219.19). Composition refers to the types and variety of living things. Structure is the physical distribution and character of components of the ecosystem. Function is the processes or interactions that occur between the living elements of the ecosystem; and connectivity is the spatial linkage between them.

Key ecosystem characteristics are identified based on the dominant ecological characteristics that describe ecosystems. Some key characteristics are agents of change and may be referred to as drivers. Some characteristics may be carried forward to inform Forest Plan components and/or long term monitoring plans depending on their relevancy to coarse and fine filter ecosystem diversity. Table 1 shows the key ecosystem characteristics the assessment team determined were important and the indicators and measures for this analysis effort.

**Table 1. Key forested vegetation characteristics of ecosystems on the Custer Gallatin National Forest**

Key Ecosystem Characteristic		Indicator	Measure
Composition	Life Form, Cover Type, Plant Distribution	Proportion of existing life form and dominant vegetation groups. Presence of individual communities of interest: aspen, whitebark pine, green aspen, paper birch, juniper, limber pine, and cottonwood.	% Area
	Tree Distribution/ Density	Presence of individual tree species by size classes (less than 5 inches and greater than or equal to 5 inches diameter classes); and trees per acre of each species.	% Area, trees per acre
Structure	Forested Size Class	Proportions of forested size classes: 0 to 5 inches: seedling/sapling; 5 to 9.9 inches small tree; 10 to 14.9: medium tree; 15 to 19.9 inches large tree; greater than 20 inches very large tree.	% Area
	Large Live Trees	Densities of large trees greater than 15 inches diameter at breast height and presence of large trees	Trees per acre, basal area per acre, % Plots



Key Ecosystem Characteristic		Indicator	Measure
	Forested Vertical Structure	Proportions by vertical structure classes (1- storied, 2-storied, 3-storied, Continuous)	% Area
	Forested Canopy Density Class	Proportions by canopy cover classes: 0 to 9% (non-forested); 10 to 24.9%; 25 to 39.9%; 40 to 59.9%; 60%+	% Area
	Dead Trees	Snags by size classes: 10 to 14.9 inches; 15 to 19.9; 20 inches+	Trees per acre
	Large Woody Debris	Quantity of large downed wood greater than 3 inches in diameter, estimated overall and by potential vegetation type	Tons per acre
	Old Growth	Amount of old growth (Green et al. definitions, 1992)	% Area
Function	Insects	Existing Infestations (aerial detection surveys)	Acres
		Proportions of hazard ratings for mountain pine beetle and/or combined beetle; Douglas-fir beetle; and western spruce budworm (no host, low, moderate, high)	% Area
Connectivity -Pattern	Stand-replacing Disturbance Pattern	Forest openings: abundance, average and range of patch size of seedling/sapling size classes, burn severity	Acres

## Scale

A framework of spatial extents is used depending on the analysis element, in order of broadest to finest:

**Ecoregions:** Ecoregions are large ecological zones covering millions of acres distinguished by common climatic and vegetation characteristics (EPA 2011). Approximately 81 percent of the assessment area is in the Middle Rockies Ecoregion. This ecoregion is located mostly in southwestern Montana, eastern Idaho, and northern Wyoming, as well as island mountain ranges in Wyoming and South Dakota. The severe, mid-latitude, humid continental climate is marked by warm to cool summers and severe winters. The mean annual temperature varies greatly by elevation and high elevations are more subarctic. Vegetation consists of coniferous forest, alpine meadow, and shrubland-grassland steppe.

Approximately 19 percent of the assessment area is in the Northwest Great Plains Province consisting of ponderosa pine – shrubland-grassland steppe. This ecoregion encompasses the Missouri Plateau section of the Great Plains in southeastern Montana, northeastern Wyoming, and the western portion of the Dakotas. The dry mid-latitude steppe climate is marked by hot summers and cold winters. The region is an unglaciated, rolling plain of shale and sandstone punctuated by occasional buttes. A small amount of the assessment area (less than 1 percent) is in the Wyoming Basin province around the Pryor Mountains consisting of semi- desert shrubland-grassland.

**Ecological Units:** The Custer Gallatin National Forest consists of Montane and Great Plains Ponderosa Pine Woodland and Savanna (Great Plains Ponderosa Pine Woodland and Savanna, 2016) ecosystems. Great Plains Ponderosa Pine Woodland and Savanna will be referred to as pine savanna ecosystems. These two units depict ecologically similar areas. Montane ecosystems of the Custer Gallatin National Forest fall within the Middle Rocky Mountain Steppe-Coniferous Forest-Alpine Meadow province. Pine savanna units of the Custer Gallatin fall within the Great Plains- Palouse Dry Steppe Province. The montane ecosystem unit includes the Hebgen Lake, Bozeman, Gardiner, Yellowstone, and Beartooth Ranger Districts and the pine savanna unit includes the Ashland and Sioux Ranger Districts.

**Montane Ecosystem:** The montane ecosystem is characterized by glaciated regions ranging with altitudinal zonation of semidesert vegetation, coniferous forests on the lower mountain slopes, and alpine tundra toward the top. Temperature and snowfall vary greatly with altitude. Winds are from the west/southwest, with much of their moisture precipitated where they cross the Pacific ranges. Due to aridity, forests are usually restricted to northern and eastern slopes. Although south- and west-facing slopes receive comparable precipitation, they are hotter and evaporation is higher. Consequently, they support fewer trees and are covered by shrubs and grasses. Lodgepole pine, Douglas-fir, subalpine fir, Engelmann spruce, limber pine and whitebark pine are the predominant conifer vegetation. The lower slopes of the mountains are dominated by grasslands and shrublands.

**Pine Savanna Ecosystem:** The pine savanna ecosystem is characterized by rolling plains and tablelands of moderate relief. The plains are notably flat, but there are occasional valleys, canyons, and buttes. Badlands and isolated mountains break the continuity of the plains. The area lies in the rain shadow east of the Rocky Mountains. The climate is a semiarid continental regime. Winters are cold and dry, and summers are warm to hot. Evaporation usually exceeds precipitation, and the total supply of moisture is low. Vegetation consists of short grasses usually bunched and sparsely distributed. Scattered trees and shrubs, such as sagebrush, are supported in all gradations of cover, from semi desert to woodland. Many species of grasses and herbs grow in this area. Grasses include grama, wheatgrass, and needlegrass. On the driest sites ponderosa pine is short and generally open grown with grass understories. Moist north-facing sites have dense stands of taller ponderosa pine, with shrub and herb understories, including species of the mountain forests to the west. Draws and gullies (ravines) that support many hardwood trees (green ash, box elder, aspen) and shrubs also dissect the landscape.

**Administrative Region:** The U.S. Forest Service Northern Region 1 encompasses Montana, North Dakota, northwestern South Dakota, and northern Idaho.

**Custer Gallatin National Forest:** The assessment area covers approximately 3,039,000 acres including private land inholdings.

**Landscape Analysis Areas:** The Custer Gallatin National Forest is broken into five unique landscape areas ranging from roughly 78,000 acres to 2.3 million acres, including private land inholdings. Within the Montane unit are the 1) Madison, Henrys Lake, Gallatin, Absaroka and Beartooth Mountains area; 2) Bridger, Bangtail, and Crazy Mountain area; and 3) Pryor Mountain area. Within the pine savanna unit are the 4) Ashland Ranger District area; and 5) Sioux Ranger District area. Table 2 below depicts the acres by analysis area.

**Table 2. Total acres and Forest Service acres by analysis area and ecological units**

Ecological Unit	Landscape Analysis Area	Total Acres (includes private inholdings)	FS Analysis Acres
Montane	Madison, Henrys Lake, Gallatin, Absaroka and Beartooth Mtns	2,343,529	2,158,640
	Bridger, Bangtail, and Crazy	321,701	205,025
	Pryor	77,944	75,067
Pine Savanna	Ashland	501,596	436,124
	Sioux	178,625	164,460

Some attributes are summarized at large scales to provide context and incorporate representative trends (for example, climate, wildfire, and insects). Most of the analysis occurs at the Custer Gallatin National Forest or landscape analysis area scales.

The temporal scale of analysis varies. Current condition analyses typically depict data collected within the last 15 years. Additional data over the last 70 years was used to assist in describing trends. The natural range of variation will depict conditions back 1,000 years ago. Assessments of trend include both short term (within several decades) and longer term predictions.

## Existing Information

In brief, the primary information used for this assessment include literature review of the best available science, Forest Service internal reports, consultation with regional experts, integrated with professional experience and the following data sources:

- **Region 1 Existing Vegetation Database (VMap):** Mapping of vegetation is based on the Region 1 vegetation database. It is a geospatial dataset developed using the Region 1 existing vegetation classification system (Barber et al. 2011). It is a remotely sensed product that is derived from satellite imagery, airborne acquired imagery, field sampling and verification. Detailed metadata for this database can be found in the project file.
- **Forest Inventory and Analysis (FIA) and the R1 Summary Database:** This analysis draws upon measurements collected on spatially balanced forest inventory and analysis grid plots. The forest inventory and analysis grid is a nationwide grid which includes 517 plots on the Custer Gallatin National Forest. This dataset is used to display estimates for the plan area because it spatially represents all National Forest System lands. Forest inventory and analysis plot data is summarized in the R1 summary database, which includes statistical reporting functions and derived attributes (Bush et al. 2016, Bush and Reyes 2015a; Bush 2015b, Bush 2014). In 2015 Region 1, in collaboration with the Remote Sensing Application Center and Interior West-FIA developed a set of protocols to re-measure forest inventory and analysis plots after they were burned by recent wildfires, this was done for the Custer Gallatin National Forest plots and used for this analysis (Bush 2015b).

**Natural Range of Variation (NRV):** The natural range of variation is part of the definition of ecological integrity and refers the variation of ecological characteristics and processes over scales of time and space that are appropriate for a given management application (Forest Service Handbook 1909.12). In contrast to the generality of historical ecology, the natural range of variation concept focuses on a distilled subset of past ecological knowledge developed for use by resource managers; it represents an explicit effort to incorporate a past perspective into management and conservation decisions (Weins et al. 2012). The natural range of variation is a tool for assessing the ecological integrity and does not necessarily constitute a management target or desired condition. Determination of the natural range of variation for vegetation components utilizes an analysis using the Simulating Patterns and Processes at Landscape Scales system (SIMPPLLE) (Chew et al. 2012). Best available science and professional experience was utilized in calibrating the model and included calibrations for historic and future climate and natural disturbances. The natural range of variation for some of the key ecosystem characteristics are presented below along with a comparison against the existing conditions. The full results of the SIMPPLLE natural range of variation analysis for the Custer Gallatin National Forest is currently being compiled and will be made available for public review when finished. It should be noted, however, that the algorithms and underlying ecological assumptions informing

the SIMPPLLE model are constantly being reviewed, improved and further developed. As such, the results presented below are subject to change. Moreover, the assessment of the natural range of variation for any key ecosystem characteristics is subject to change during the development and implementation of the revised Forest Plan as current science, technology and our ecological understanding improves.

- Aerial Detection Survey (ADS): Survey data and condition reports that estimate levels of tree mortality and defoliation resulting from insects and diseases (<http://www.fs.usda.gov/detail/r1/forest-grasslandhealth/?cid=stelprdb5366459>).
- Forest Activity Tracking System (FACTS): Is the current activity tracking database in which all management and natural events are recorded. Information from this database is used to quantify the extent and type of management actions that have occurred. Currently, both spatial and tabular information is required when activities occur on National Forest System lands. The geographic information tool was used to create the maps of past harvest, fire, and fuels activities found in appendix A. The forest activity tracking system database is the newest of several activity tracking databases developed over the years and used by the Forest Service in Region 1; older records from previous systems such as the Timber Stand Management Record System (TSMRS) are incorporated into forest activity tracking system. The earliest activity records date back generally to the 1940s or 1950s, when activity tracking protocols were adopted. Older records are likely not as accurate due to improvements in modern record keeping. Site-specific records of early harvest activities during the initial settlement of the area are not available or summarized quantitatively in the Assessment, but are addressed qualitatively using other information sources such as boundary report notes compiled when the National Forest Reserves were first proposed.

A variety of methods were utilized to assess forested vegetation including the following:

- Summarization of existing geospatial information systems (GIS) data
- Summarization of forest inventory and analysis grid data
- Literature review of the best available science
- Vegetation modeling to characterize the natural or historic range of variability (Chew et al. 2012)
- Consultation with regional experts and partners

## Current Forest Plan Direction

The record of decision for the 1986 Custer National Forest Land and Resources Management Plan was signed on June 10, 1987. The record of decision for the Land and Resources Management Plan and Environmental Impact Statement for the Gallatin National Forest was signed on September 23, 1987.

The Custer National Forest Plan identified approximately 46 percent of the tentatively suitable forest lands as part of the suitable timber base (72,360 acres) and the Gallatin National Forest Plan identified 69 percent (305,000 acres). The Custer National Forest Plan provided for an annual harvest of 3.5 million board feet and the Gallatin National Forest Plan an annual harvest of 21 million board feet. In general, the timber management goals for the two forest plans are fairly similar for both the suitable lands and the unsuitable. They both provide for jobs, vegetation diversity, and multiple-use management as indicated below for forested vegetation:

## **Gallatin National Forest Plan – Timber Management Goals (USDA Forest Service 1987b)**

- Achieve the objectives of multiple-use management as well as to provide jobs (record of decision, p. 9).
- Timber harvest benefits – provide roads to NF and establish diversity in species, age, and size (record of decision, p. 22).
- Provide for: timber supply, adequate distribution of age classes over the Forest, reduce the threat of fire, and provide an opportunity to treated insect and disease-infested timber (record of decision, p. 22).
- Future Condition - Progress towards a more balanced distribution of vegetation size and age classes through timber harvest (overview, p. 5).
- Timber program used as a management tool to create age class diversity, to salvage dead trees, to reduce insect and disease losses and fire hazards, and to meet other resource objectives such as providing access for recreation (overview, p. 16).
- Timberlands have multiple resource objectives such as providing wildlife habitat, recreation opportunities, and livestock grazing. The forest plan ensures that timber management activities are properly planned and integrated to meet multiple objectives while protecting other resource values (overview, p. 16).
- Goal - Provide a sustained yield of timber products and improve the productivity of timber growing lands (p. 11-1).
- Objective – Timber harvest will be used as a tool to carry out vegetative management (p. 11-5). Vegetative Diversity – Strive to develop a variety of successional stages (p. 11-20). Insect and Disease – Long term losses by insects and diseases will be reduced by integrating forest pest management through use of silvicultural treatments to improve the diversity of tree species and the size and age of trees in various stands (p. 11-22).
- Management Area Goals (MAs 5, 7, 8, 9, 10, 11, and 24) – Provide for productive timber stands and optimize timber growing potential (p. 111-34). Develop distribution of age classes to optimize sustained timber production and improve vegetation diversity (p. 111-24). Wildlife emphasis areas – Base management on vegetation characteristics needed for featured wildlife species (p. 111-33 to 36, 40 to 43). Recreation, trail corridors, riparian emphasis areas – permit harvest to provide for diversity of vegetation pattern and in recreation settings allow for hazard reduction. Unsuitable areas – allows for harvest of post and poles and other wood products in areas adjacent to roads.

## **Custer National Forest Plan – Timber Management Goals (USDA Forest Service 1987a)**

- Forestwide Standard - Timber harvest as a tool to maintain or create the necessary vegetative diversity and stand condition to maintain and provide adequate thermal and security cover for whit-tail deer (record of decision, p. 24). Timber management to provide opportunities for local jobs (record of decision, p. 24)
- Forestwide Goal - The goal of timberland management is to harvest timber within sustained-yield capability to help maintain timber dependent communities, forest health, vigor, productivity,

provide vegetative diversity for wildlife, eliminate tree encroachment on selected livestock grazing areas, and provide for scenic resources (p. 4).

- Management Standards – Maintain a variety of age classes. Size and shape of individual treatment units guided by characteristics of stand and area and consideration of all resource objectives. Insect and disease infected timber will be managed in coordination with other resources. Strategies to treat and prevent insect and disease problems include providing for age-class diversity, early slash cleanup, and stocking control (p. 24).
- Suitable timber lands in timber emphasis area (MA G) - manage for the maintenance and improvement of a healthy diverse forest and as a source of wood product for dependent local markets (p. 64)
- Suitable timber lands in non-timber emphasis areas (MAs B, C, D, E, F, M, and R) – Livestock, wildlife, minerals, recreation, riparian, woody draws, and municipal watershed emphasis areas vegetation management is allowed as long as can improve or meet the resource goals and values of the management area (p. 46, 50, 54, 58, 62).
- Unsuitable timber lands – vegetation management allowed (post and poles) for maintenance of recreation facilities (p. 67). Recreation low development areas – allows for veg management to enhance wildlife habitat and as long as roading is not required (p. 73). Historic landmarks – removal of diseased or safety hazards only (p. 86). Administration sites – vegetation management to protect or maintain other values (p. 88). Wild Horse Territory – harvest of dead or down material, firewood and post and poles for maintenance of improvements (p. 89). Scenic highway – timber harvest posts, poles and firewood as long as it maintains or enhances the visual resource (p. 98).

## Existing Condition

### Potential Forested Vegetation

#### Types

Potential natural vegetation is based on a climax successional theory which states that vegetation communities are constantly changing and moving toward an endpoint, or “climax” (Pfister et al. 1977). Potential natural vegetation can be represented by classification systems that define potential vegetation types to describe the climax state. Plant communities that develop over time given no major disturbances are similar within a potential vegetation type. These can then serve as references to understand site productivity, biodiversity, pattern of existing and future vegetation, growth potential, species distribution, and disturbance type and frequency. Given the role of disturbances on the Custer Gallatin National Forest landscapes, potential vegetation types are not used to suggest that the climax state is desirable or achievable. Existing vegetation, however represents a single point along the successional pathway of a potential vegetation type and varies depending on each site’s unique history.

Habitat types are used to classify potential vegetation (Pfister et al. 1977). The Custer Gallatin National Forest has utilized Region 1 habitat type groups to assist in describing ecosystem diversity (Milburn et al. 2015, Reid et al. 2016). Nine of these habitat types occur on the Custer Gallatin National Forest and are defined in the table below. These habitat type groups are groupings of habitat types having similar biophysical characteristics, with similarities in historical disturbance regimes that have affected a similar range of tree composition, structural characteristics, productivity, and successional trends into mature forests (ibid). These groups provide the basis to defining ecosystems. Since habitat types are relatively

static, they can be used to stratify the landscape to estimate key ecosystem characteristics and provide a meaningful depiction of ecosystem diversity. See Figures 106 through 110 in Appendix A for mapped Jones potential vegetation for vegetation using the Region 1 existing vegetation database and Table 62 in Appendix A for a summary of those acres by analysis area.

For monitoring trends regionally these habitat type groups have been further grouped up into a broad potential vegetation groups as displayed in Table 3 (Milburn et al. 2015, Reid et al. 2016).

**Table 3. Forested potential vegetation groups for the Custer Gallatin National Forest**

Broad Potential Veg Group	Habitat Type Group	Description
Warm Dry	Hot Dry	The driest potentially forested sites adjacent to or within the ecotone with grass/shrubland. Limber pine is the climax species. Tree species that may be dominant include limber pine, juniper, and ponderosa pine. These sites would historically burn with frequent low severity fires that would maintain an open savannah condition of these early seral species or grass/shrub conditions.
	Warm Dry	Ponderosa pine habitat types where ponderosa dominates all phases and natural frequent fire would maintain open conditions. This group also contains the driest Douglas-fir habitat types, where open-grown ponderosa pine or Douglas-fir with bunch grasses would dominate given a natural frequent low severity fire regime <sup>1</sup> ; without disturbance, Douglas-fir eventually dominates. On the pine savanna unit only ponderosa pine occurs.
	Moderately Warm Dry	This group includes more moist Douglas-fir habitat types, where frequent disturbance would usually maintain open-grown ponderosa pine or Douglas-fir with grass and brush understories <sup>1</sup> . These types can also support a mix of lodgepole pine or western larch. Stands become dense and dominated by Douglas-fir over time with no disturbance. On the pine savanna unit only ponderosa pine occurs.
	Moderately Warm Moderately Dry	Regionally, this group is typified by grand fir types not present on the Custer Gallatin National Forest. It also includes productive Douglas-fir habitat types that could occur on the Custer Gallatin National Forest, where Douglas-fir or lodgepole pine can dominate. The natural fire regime would have been mixed severity to create a mosaic of even-aged and/or open stands of Douglas-fir. Components of ponderosa pine can occur.
Cool Moist	Cool Moist	Moist subalpine fir and dry Engelmann spruce habitat types, where site conditions support high species diversity which may include Douglas-fir, Engelmann spruce, lodgepole pine, and subalpine fir <sup>1</sup> . Some sites may be dominated by lodgepole pine after stand-replacing fire <sup>1</sup> .
	Cool Wet	The moistest Engelmann spruce and subalpine fir habitat types. They are generally forested riparian areas along streams or associated with wetlands where the natural fire interval is usually long <sup>1</sup> . Often the climax species dominate. Douglas-fir, lodgepole pine, aspen or other hardwoods can be present.
	Cool Moderately Dry to Moist	Drier subalpine fir and Engelmann spruce habitat types and most lodgepole pine habitat types which are often dominated by lodgepole pine under a natural regime of infrequent, stand replacing wildfire. Mixed severity fires were also common and can promote a mosaic of lodgepole pine, Douglas-fir, and possibly whitebark pine although it tends to not have a competitive advantage.
Cold	Cold	The highest elevation subalpine fir and lodgepole pine climax types, where whitebark pine may be present with lodgepole pine, subalpine fir, and Engelmann spruce. Most natural fires were low severity because of discontinuous fuels, although high severity occurred at long intervals <sup>1</sup> . Whitebark pine would be favored with a natural fire regime.
	Timberline	Whitebark pine climax types on the Custer Gallatin National Forest. Whitebark pine is usually both the existing and climax vegetation because these types are above the cold limits of most other species <sup>1</sup> ; the natural fire regime was variable including low

Broad Potential Veg Group	Habitat Type Group	Description
		and mixed severity (generally 35-300+ year intervals) as well as stand-replacing fires at long intervals.

<sup>1</sup>USDA 2005.

**Table 4. Percent Region 1 habitat type groups by landscape analysis area and ecological unit, R1 summary database, forest inventory and analysis plots**

	Landscape Analysis Area					Ecological Unit	
	Ashland	Bridgers Bangtails Crazies	Madison, Henrys Lake, Gallatin, Absaroka and Beartooth Mtn	Pryors	Sioux	Montane	Pine savanna
Cold	0.00%	16.13%	30.63%	8.33%	0.00%	28.68%	0.00%
Cool Mod Dry to Moist	0.00%	26.61%	18.83%	6.25%	0.00%	19.07%	0.00%
Cool Moist	0.00%	1.61%	6.79%	8.33%	0.00%	6.40%	0.00%
Cool Wet	0.00%	0.00%	5.09%	8.33%	0.00%	4.77%	0.00%
Hot Dry	0.00%	5.38%	2.70%	16.67%	0.00%	3.38%	0.00
Mod Warm Dry	12.68%	22.58%	11.73%	8.33%	32.76%	12.53%	18.50%
Timberline	0.00%	16.13%	7.64%	0.00%	0.00%	8.11%	0.00%
Warm Dry	62.56%	0.00%	1.93%	14.58%	13.79%	2.18%	48.42%
Non-forested	24.76%	11.56%	14.66%	29.17%	53.45%	14.88%	33.08%
Total	100%	100%	100%	100%	100%	100%	100%

#### *Madison, Henrys Lake, Gallatin, Absaroka, and Beartooth Mountains*

All eight of the forested habitat type groups that occur on the Custer Gallatin National Forest are present in this landscape. Cool to cold types have the highest dominance of all analysis areas (61.34 percent). Timberline habitat type, which is dominated by whitebark pine represents 7.64 percent of the area. Hot dry to warm types make up about 16.36 percent. Individually, hot dry and warm dry are least represented. Non-forested habitat types makes up about 14.66 percent of the area.

#### *Bridger, Bangtail, and Crazy Mountains*

This analysis area contains six of the eight forested habitat type groups. Cool to cold types are most dominant (44.35 percent). Hot to warm types (27.96 percent) is the second most dominant types. Timberline habitat which is dominated by whitebark pine has the highest percent of all analysis areas (16.13 percent). Cool moist is uncommon at 1.61 percent. This area has the smallest representation of non-forested habitat types (11.56 percent).

#### *Pryor Mountains*

The Pryor landscape area has the largest presence of hot dry types (16.67 percent). Non-forest types has the second highest representation of all analysis areas (29.17 percent). The timberline type is



absent. Cool to cold types occur on 31.24 percent and warm types on 22.91 percent. Seven of the forested habitat types are represented.

The montane unit (above 3 landscape areas) has a diversity of habitat type groups with all eight types represented. It is dominated by the cool to cold types (58.92 percent). Hot to dry types represent 18.06 percent and timberline type 8.11 percent. Non-forest types make up 14.88 percent. Hot dry and warm dry occur in very small proportions.

#### *Ashland District*

Ponderosa pine is the only needled conifer species that occurs, making this landscape very different than the montane unit. Thus only two of the eight forested habitat types are represented. The greater landscape is generally characterized as an island of ponderosa pine trees surrounded by crop, hay, and pasture lands. Two forested types occur and are collectively grouped into a broader vegetation type of warm dry (Table 4 above). Warm dry types make up 75.23 percent and non-forest types make up 24.77 percent. Large wildfires have impacted this landscape as indicated in the difference between potential vegetation type (habitat type) and existing cover type which will be discussed below. These habitat type groups do not represent existing forested vegetation coverage.

#### *Sioux District*

This landscape has the highest amount of non-forested types of all the land areas (53.45 percent). Like with the Ashland district ponderosa pine is the only needled conifer species. Two of the eight habitat types occur, which are warm dry (13.79 percent) and moderate warm dry (32.76 percent).

The pine savanna unit is dominated by a forested habitat types (66.92 percent), the rest is non-forested types. Less diversity in forest types occur due to potential of site to support other species. Non-forested types have the largest presence on the Custer Gallatin National Forest on this landscape.

### **Trends**

Potential vegetation types can generally be considered to be static as they are based on physical site factors. Shifts in moisture, temperature and other factors resulting from climate change could actually change potential vegetation types of a site over time.

### **Composition**

#### **Lifeform**

Existing vegetation is not the same as potential vegetation described earlier. Species that currently exist on a site are a representation of a point in time in a successional pathway of a potential vegetation type. Species composition on landscapes are very complex and changes through time based on successional pathways and disturbances.

The broadest depiction of existing vegetation is lifeform. Lifeform is a classification of plants based on their size, morphology, habit, life span, and woodiness (Barber et al. 2011). Region 1 uses lifeform in its existing vegetation classification system, and includes tree, shrub, herbaceous (grass and forb), and sparsely vegetated. Classification is determined by trees per acre, basal area per acre, and canopy cover (ibid). Tree lifeform is classified from inventory data if there are at least 20 square feet of basal area per acre or at least 100 trees per acre. Shrub, grass, and forb are classified they have at least 10 percent canopy cover. Sparse vegetation has canopy cover of trees, shrubs, grass, and forbs of at least 1 percent and less than 10 percent; non-vegetated has a combined canopy cover of less than 1 percent.

Currently there is a diversity of lifeform representation across the Custer Gallatin National Forest administrative boundary. In portions of the forest tree lifeform dominates and other areas herbaceous no tree lifeforms dominate. Figure 1 and Figure 2, and discussion below depicts this representation for the landscape analysis areas and ecological units.

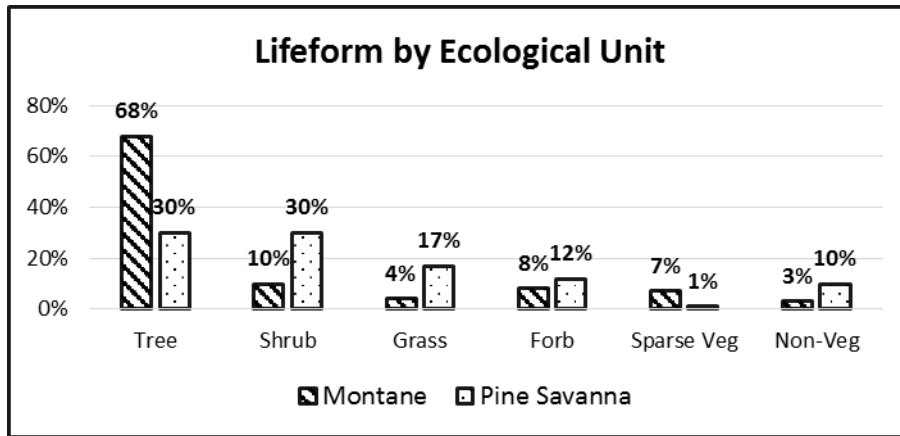


Figure 1. Proportion of lifeform by ecological unit, R1 summary database, forest inventory and analysis plots

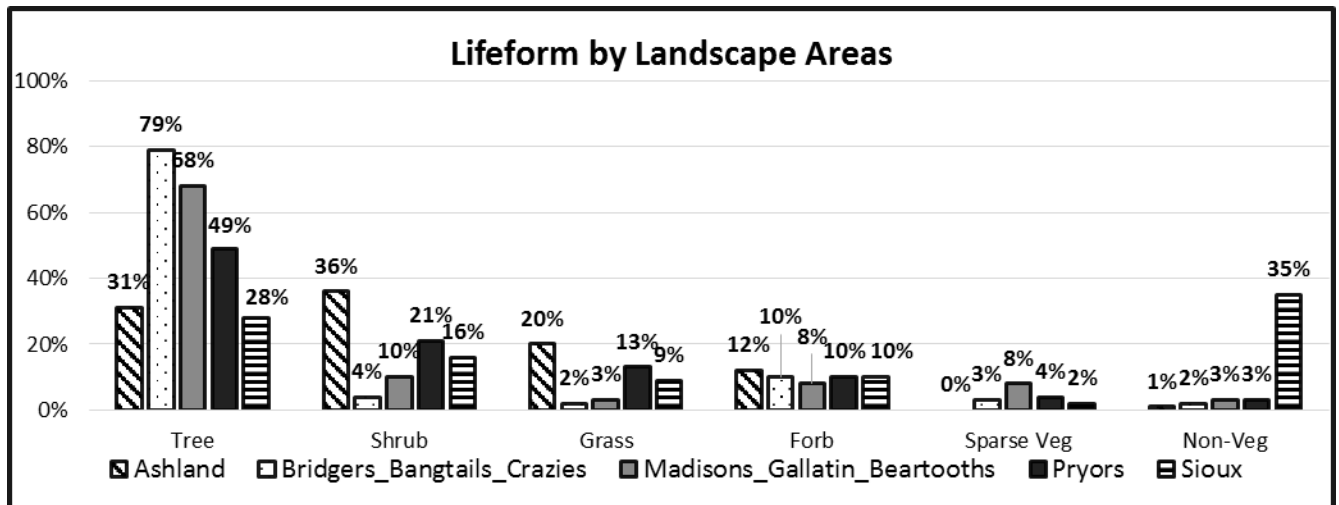


Figure 2. Proportion of lifeform by landscape areas, R1 summary database, forest activity tracking system plots

#### *Madison, Henrys Lake, Gallatin, Absaroka, and Beartooth Mountains*

These areas combined have a dominant tree lifeform estimated at 68 percent, the second highest of all units. Forb, shrub, grass, sparse vegetation, and non-vegetation combined make up the remaining 32 percent. Shrub and forb lifeform make up 18 percent of the non-tree life form. See Figure 2.

#### *Bridger, Bangtail, and Crazy Mountains*

These areas combined have a dominant tree lifeform estimated at 79 percent, the highest of all the montane unit. Forb, shrub, grass, sparse vegetation, and non-vegetation combined make up the remaining 21 percent; with shrub, forb, and sparse veg at 10 percent, 8 percent, and 8 percent. See Figure 2.

### *Pryor Mountains*

The Pryor landscape area has a dominant tree life form estimated at 49 percent. Non tree lifeform is more dominant on this unit and makes up 51 percent. Shrub lifeform is at 21 percent.

The montane unit (above 3 landscape areas) have a dominant tree life form at 68 percent. The non-forest tree life forms are dominated by shrub, forb, and sparse vegetation. Grass and non-vegetation make up 7 percent. See Figure 1.

### *Ashland District*

Shrub is the dominant life form (36 percent). Thirty one percent has an existing tree lifeform. The remaining non forest tree life form (33 percent) is dominated by grass and forb lifeform. See Figure 2. Existing Lifeform representation has been shaped from large fires the past 28 years due primarily from the loss of ponderosa pine tree cover.

### *Sioux District*

This land unit is dominated by a non-veg lifeform (35 percent). Tree lifeform is at 28 percent. The remaining non-tree lifeforms (37 percent) is dominated by shrub (16 percent) and forb (10 percent) and grass (9 percent). See Figure 2. This landscape area has had lifeform changes due to large fire disturbances since 1988. This should be bumped to trend.

The pine savanna unit is dominated by tree (30 percent) and shrub (30 percent) lifeform. The remainder 40 percent is dominated by grass (17 percent), forb (12 percent), and non-vegetation (10 percent) lifeforms. See Figure 1

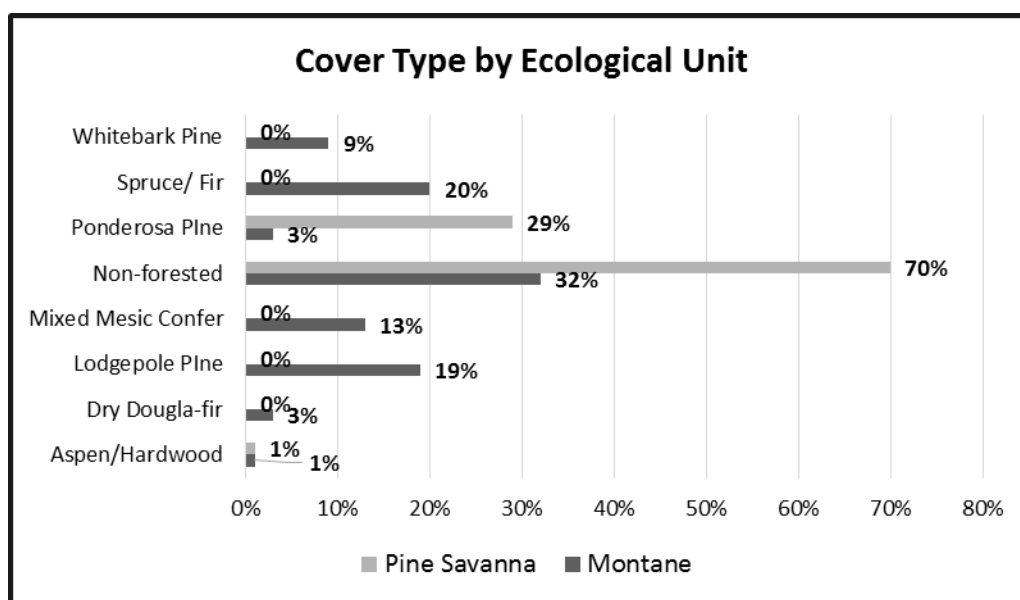
## Cover Type

Region one classification for existing vegetation includes dominance types, which represents broad species groups of dominant vegetation (Milburn et al. 2015, Reid et al. 2016). Dominance types are grouped into broad groups of existing vegetation called Region 1 cover types. Unlike potential vegetation which is relatively static, cover type changes through time based on successional pathways and disturbances. Presence and distribution of cover types is important to understanding ecosystem diversity and function across the Custer Gallatin National Forest. Cover types that occur on the Custer Gallatin and representation within each analysis landscape are described below.

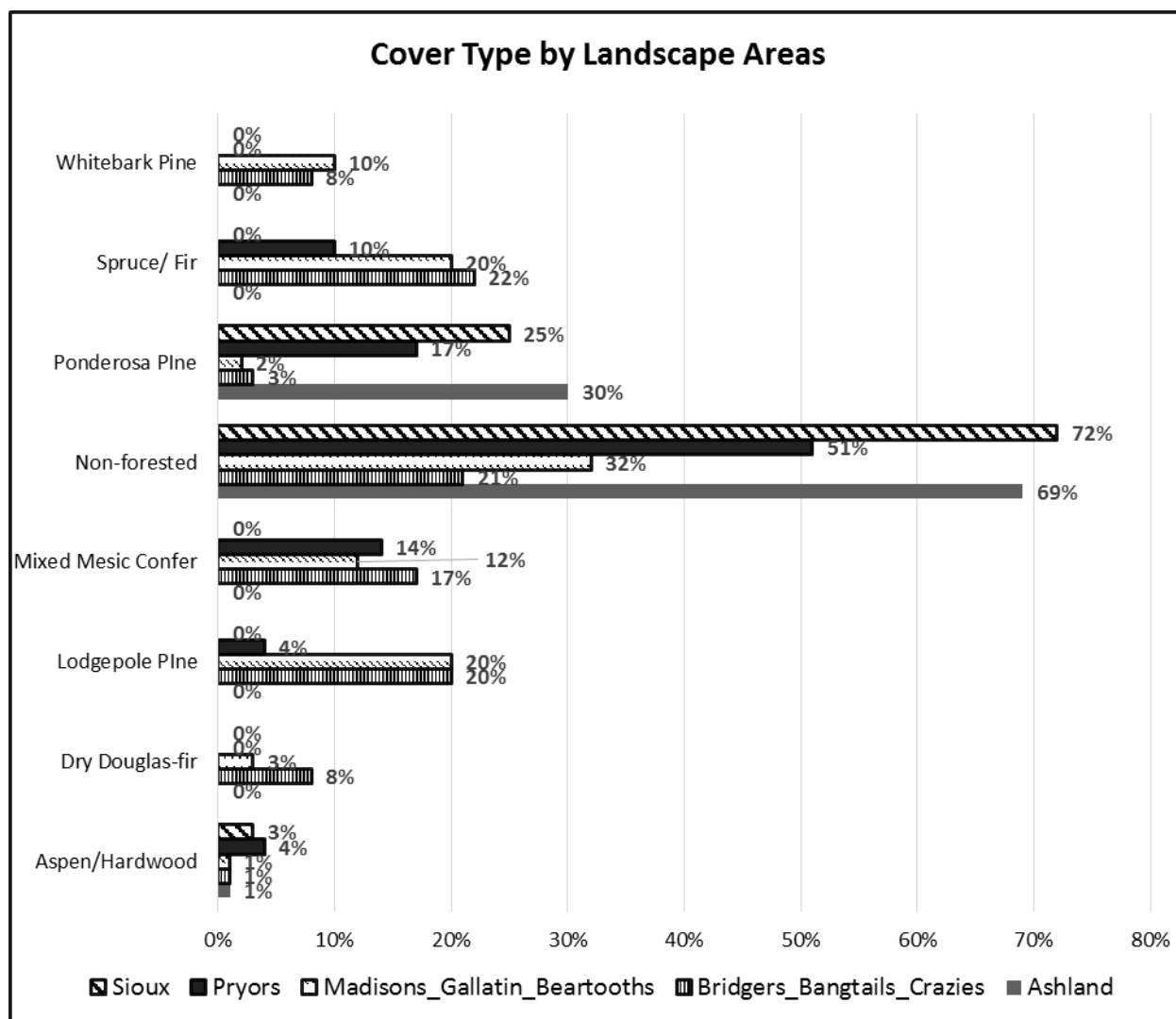
**Table 5. Forested and non-forested cover types**

<b>Cover Type</b>	<b>Description</b>
Non-Forested	Includes non-forest dominated cover types: grass, dry shrub, riparian grass/shrub. These are further defined and discussed in the non-forested assessment (Reid 2016).
Ponderosa Pine	This cover type includes sites dominated by ponderosa pine, juniper, or limber pine. A minor component of Douglas-fir can be present. Ponderosa pine is an early seral, shade intolerant, fire resistant species that is found on a narrow elevation band between non-forested ecotones and Douglas-fir. This type usually grows on the warm dry forested habitat type group, but also on hot dry and moderately warm and dry. Ponderosa pine is the only conifer cover type on the pine savanna landscapes of the Custer Gallatin National Forest.
Dry Douglas-fir	Dry sites dominated by Douglas-fir, with potential components of ponderosa pine, limber, or juniper. Douglas-fir is one of the most common species on the montane landscapes of the Custer Gallatin National Forest. It is moderately shade and drought tolerant, which enables it to function as both an early and late seral species. This type occurs commonly on warm dry, moderately warm dry, and moderately warm moderately dry habitat type group.

Cover Type	Description
Mixed Mesic Conifer	Sites dominated by Douglas-fir which can be mixed with lodgepole pine, and/or subalpine fir/spruce. This type is found on sites more moist and productive than the dry Douglas-fir type. This cover type is found most commonly on cool moderately dry to moist habitat type groups, but can also occur on cool moist types or moderately warm moderately dry.
Lodgepole Pine	Sites dominated by lodgepole pine with minor components of other species. Lodgepole pine is a very abundant species on the montane landscapes of the Custer Gallatin National Forest, growing under a wide range of conditions. Where dominant it is often single-storied. Without disturbance it succeeds to Douglas-fir, spruce, and/or subalpine fir. This cover type can occur on multiple habitat type groups, most commonly cool moderately dry to moist.
Aspen /Hardwood	Areas dominated by aspen, cottonwood, and birch, often with shrubs such as willow and alder. This type often occurs in association with riparian and moist upland areas. Without disturbance, conifers will eventually dominate. This cover type can be found in almost all habitat type groups.
Spruce/fir	Subalpine fir and/or Engelmann spruce dominate, with minor components of other species. These are often climax forests. Where these shade-tolerant climax species have become dominant, stands are usually multi-layered and dense. This cover type can occur on any of the habitat types in the broad cool moist or cold potential vegetation groups.
Whitebark pine	The whitebark pine cover type occurs at the high elevations, commonly on the cold habitat type group (where it is perpetuated by disturbance) or timberline habitat type group (where it is the most common dominant). Alpine larch is a potential component but is not known to occur on the Custer Gallatin. Minor components of subalpine fir, spruce, Douglas-fir, limber pine, or lodgepole pine may occur. Whitebark is a shade intolerant, moderately fire resistant species. Ongoing mortality due to the exotic blister rust fungus has reduced its extent.



**Figure 3. Proportion of cover type by ecological unit, R1 summary database, forest inventory and analysis plots**



**Figure 4. Proportion of cover type by landscape areas, R1 summary database, forest inventory and analysis plots**

#### *Madison, Henrys Lake, Gallatin, Absaroka and Beartooth Mountains*

Spruce/fir (20 percent), lodgepole (20 percent), mixed mesic (12 percent), and whitebark pine (10 percent) make up the dominant cover types. Dry Douglas-fir (3 percent), ponderosa pine (2 percent), and aspen/hardwood (1 percent) have less presence in the area. Non-forested cover types make up 32 percent of the area. See Figure 4.

#### *Bridger, Bangtail, and Crazy Mountains*

This area is dominated by spruce/fir (22 percent), mixed mesic (17 percent), and lodgepole pine (20 percent). Less dominant cover types are whitebark pine (8 percent), dry Douglas-fir (8 percent), ponderosa pine (3 percent), and aspen/hardwood (1 percent). Bangtails by itself does not contain a whitebark pine cover type. Non-forested cover types make up 21 percent. See Figure 4.

### *Pryor Mountains*

The Pryor landscape area has a dominant non-forested cover type (51 percent). Ponderosa pine (17 percent), mixed mesic (14 percent), and spruce/fir (10 percent) are the dominant tree cover types. Aspen/hardwood (4 percent) and lodgepole pine (4 percent) cover types have a minor presence. This area has no whitebark pine or dry Douglas-fir cover types represented. See Figure 4.

The montane unit (above 3 areas) has a dominant cover type of spruce/fir (20 percent), lodgepole pine (19 percent), and mixed mesic (13 percent). Whitebark pine (9 percent), dry Douglas-fir (3 percent), and ponderosa pine (3 percent) are less dominant. Aspen/hardwood cover type is least represented at 1 percent. Non-forest cover type makes up 32 percent. See Figure 3.

### *Ashland District*

Ashland area is dominated by a non-forested cover type (69 percent). Existing ponderosa pine cover type is at 30 percent, which has been reduced from potential from large disturbances the past 28 years. Aspen/hardwood cover type is a minor cover type (1 percent). Figure 4

### *Sioux District*

This area is dominated by a non-forested cover type (72 percent). Existing ponderosa pine cover is at 25 percent. Large disturbances the past 28 years has reduced the potential conifer tree cover. Aspen/hardwood cover type is a minor component (3 percent). See Figure 4.

The pine savanna unit is currently dominated by a non-forested cover type (70 percent). Ponderosa pine cover type represents 29 percent of the area, while aspen/hardwood is a minor cover type at 1 percent. See Figure 3.

## **Trend**

### *Lifeform and Cover Type*

Cover types and life forms are not static and can change at any point in time, especially when stand replacement type disturbances occur. Stand replacement disturbances will reset the life form from tree to shrub, forb, or grass depending on site characteristics and other vegetation types present. Without disturbance cover types slowly transition from early seral, shade intolerant species to late seral, shade tolerant species. Fire exclusion the last 90 or so years has resulted in a higher proportion of late seral, shade tolerant species at the expense of shade-intolerant types. This trend is one of the most documented and studied effect of fire exclusion (Keane et al. 2002) and is true on the Custer Gallatin National Forest where disturbances have not occurred. This is even more apparent in forest types with a natural high frequency, low severity fire regimes, such as the hot dry and warm dry habitat type groups on the Custer Gallatin. Generalized successional trends of cover types on the montane unit without disturbance include:

- Hot dry to warm dry habitat type groups where ponderosa pine or limber pine are seral components will trend to Douglas-fir.
- On more mesic warm types Douglas-fir can act as an early seral and will trend towards subalpine fir or spruce.
- On sites where whitebark pine is seral these will trend to subalpine fir.
- Lodgepole pine types will trend towards spruce or subalpine fir without stand replacement disturbance or small scale disturbance such as individual tree or small groups of mountain pine

beetle mortality. Stand replacement disturbances in this type tends to perpetuate lodgepole cover type.

Many of these trends are occurring where stand replacement fire or regeneration harvest has not occurred in the several decades. Climate change effects on disturbance processes could interrupt this trend and reset the life form and reset the successional pathway.

Cover types on the pine savanna units do not transition to late seral species, due to a single conifer cover type (ponderosa pine), however these landscapes transition to high tree densities and multi canopy layers with fire exclusion which is discussed in the structure section.

As noted above life form can transition from one type to another where as potential vegetation is generally considered to be static. When stand replacement disturbances occur in a forested potential vegetation the life form will temporarily change to a non-tree life form until forest cover is reestablished. This effect from recent stand replacement disturbances (last 16 years) can be seen by comparing acres of existing life form to acres of potential vegetation. The pine savanna unit has had the largest change in lifeform. Individually the Ashland District has had the largest change at 44 percent. The Bridgers Bangtails Crazies unit has had the smallest at 9 percent. Depending on reforestation success, these areas will likely be returning to a tree life form over the next 5 to 80 plus years as they recover from these large wildfires. Artificial planting is likely to occur on some of this acreage where seed source is lacking.

**Table 6. Proportion of existing tree life form and potential forested vegetation by analysis area and ecological unit, R1 summary database, forest inventory and analysis plots**

Analysis Area/Ecological Unit	Proportion of Forested Habitat – Potential Vegetation	Proportion of Existing Tree Lifeform	Difference
Madison, Henrys Lake, Gallatin, Absaroka and Beartooth Mtns	85%	68%	17%
Bridger, Bangtail, Crazies	88%	79%	9%
Pryors	71%	49%	22%
Ashland	75%	31%	44%
Sioux	47%	28%	19%
Montane	85%	68%	17%
Pine Savanna	66%	30%	36%

## Information Needs

A quantitative analysis for life form and cover type is currently being conducted using the SIMPPLLE model to determine a natural range of variability. When this is complete, it will be used in addition to information presented above to further assess ecological integrity for this key ecosystem characteristic.

## Plant Distribution - Presence of Individual Species of Interest

Presence of individual species of interest by proportion of the forested landscapes identified in the key ecosystem characteristic tables are displayed in Figure 5 **Error! Reference source not found.** through Figure 9 below. Tables are provided below for the presence of the species of interest to display how they occur across the landscape, see the non-forested assessment (Reid 2016) for a detailed discussion on aspen, green ash, paper birch, juniper, and cottonwood. Whitebark pine and limber pine are discussed in detail below.

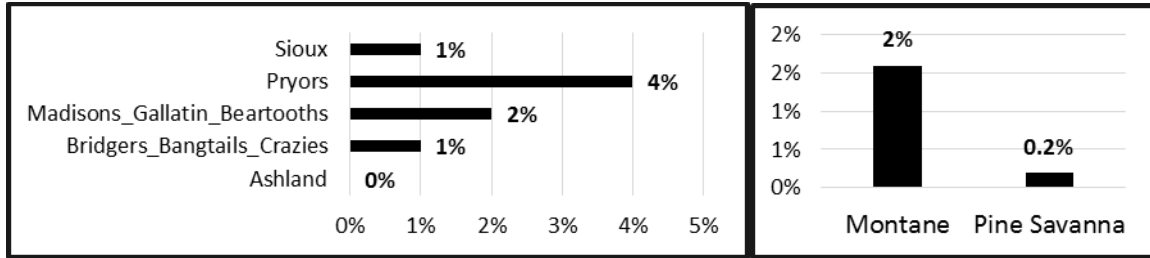


Figure 5. Presence of aspen by proportion of analysis area and ecological unit, R1 summary database, forest inventory and analysis plots

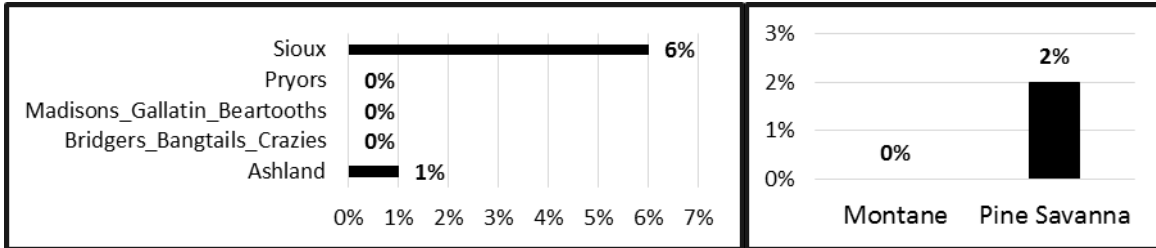


Figure 6. Presence of green ash by proportion of analysis area and ecological unit, R1 summary database, forest inventory and analysis plots

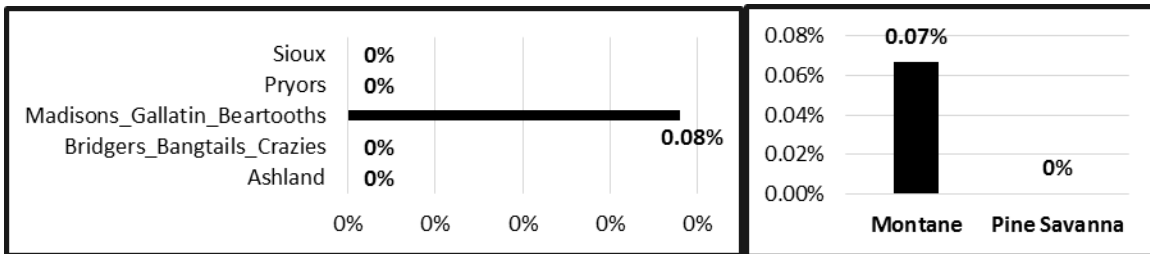


Figure 7. Presence of paper birch by proportion of analysis area and ecological unit, R1 summary database, forest inventory and analysis plots

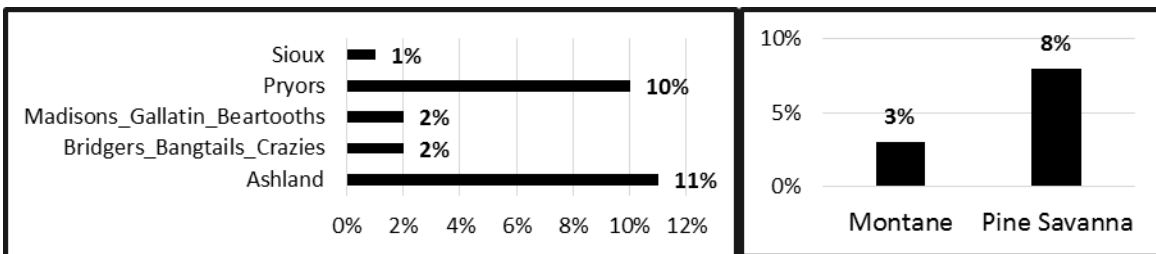
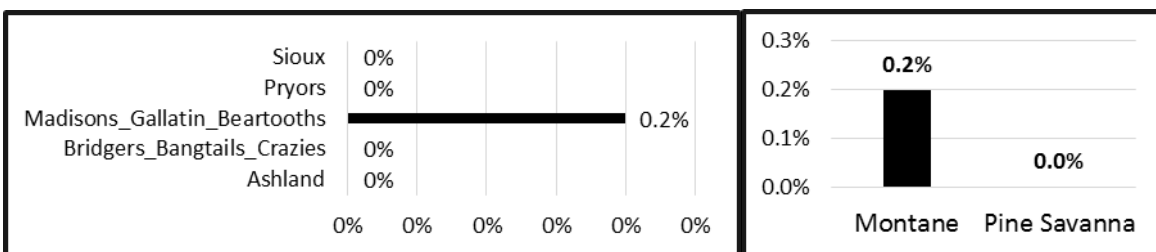


Figure 8. Presence of juniper by proportion of analysis area and ecological unit, R1 summary database, forest inventory and analysis plots





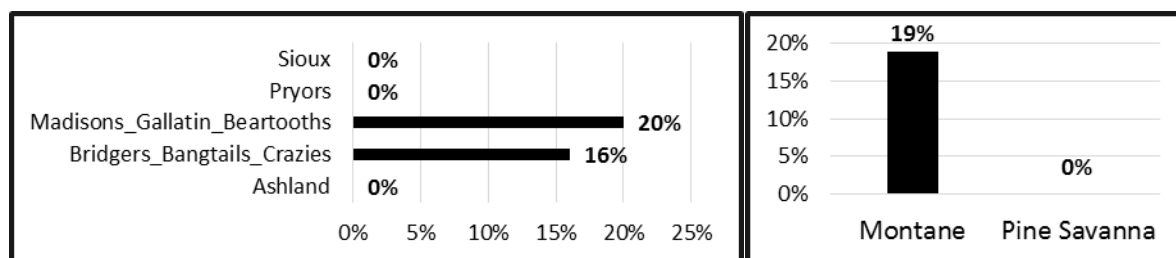
**Figure 9. Presence of cottonwood by proportion of analysis area and ecological unit, R1 summary database, forest inventory and analysis plots**

## Whitebark pine

Whitebark pine is considered both a foundation and a keystone species. A keystone species is a species that has a disproportionately large effect on its environment relative to its abundance. As a foundation species it plays an ecological role in defining ecosystem structure, function and process (Tomback et al. 2001). Whitebark pine is often the first colonizer on high elevation sites with difficult growing conditions (high snow loads, poor soil development, and short growing seasons). Whitebark pine plays a role in regulating soil development, carbon storage, and capturing and retaining snow, which increases the quantity and duration of summer runoff (ibid). This lengthened snow melt provides water to feed streams and riparian communities longer into the growing season (USDA 2006). Whitebark pine has a large protein rich seed that are an important food source for birds, squirrels, black and grizzly bears and other mammals (Tomback et al. 2001, IBGST 2013). Because of its large size it is not wind disseminated and it relies almost exclusively on Clark's nutcrackers for seed dispersal (USDA 2006).

Based on forest inventory and analysis data, whitebark pine is present on approximately 420,000 acres on the Custer Gallatin National Forest. Habitat for whitebark pine does not occur on the prairie unit. Only the Bridgers Bangtails Crazies and the Madison, Henrys Lake, Gallatin, Absaroka and Beartooth analysis units contain whitebark pine. The largest extent of whitebark pine occurs on the Madison, Henrys Lake, Gallatin, Absaroka and Beartooth unit on about 390,270 acres (20 percent of the analysis area – see Figure 10 below). The Bridgers Bangtails Crazies unit has 30,150 acres with whitebark pine present (16 percent of the analysis area – see Figure 10 below). On a broader landscape, whitebark pine is found on 10 percent or 2.5 million acres of the 24-million-acre Greater Yellowstone Area (GYCC 2011).

Whitebark pine can be found in pure stands on harsh, high-elevation sites and in mixed conifer stands below the timberline. The Madison, Henrys Lake, Gallatin, Absaroka and Beartooth Mountains unit has slightly more whitebark pine in the 5 inch or greater size class than in the less than 5 inch size class (see Appendix Table 60). The Bridgers Bangtails Crazies unit has a wider spread and is more dominated by the  $\geq 5$  inch size class (see Appendix Table 60). In the Madison, Henrys Lake, Gallatin, Absaroka and Beartooth Mountains unit this may be due to increased mortality from mountain pine beetle, blister rust and or fire disturbances in the past and newer cohorts have established post disturbances or smaller, younger trees are being less impacted by blister rust. In the Bridgers Bangtails Crazies unit the prevalence of larger trees may indicate a lack of seed or suitable seed beds for new trees to establish. See potential vegetation types, cover types, tree distribution/density, and ecosystem integrity sections for further information on where whitebark pine is found on the Custer Gallatin.



**Figure 10. Presence of whitebark pine by proportion of analysis area and ecological unit, R1 summary database, forest inventory and analysis plots**

Throughout its range, whitebark pine is currently at significant risk from both the nonnative white pine blister rust (*Cronartium ribicola*) and the native mountain pine beetle (*Dendroctonus ponderosae*) (Logan et al. 2010). Climate change effects, including warmer temperatures and altered precipitation patterns, increase the reproductive rate and survival of mountain pine beetle (Raffa et al. 2008). Overstory mortality from these agents is unprecedented in many areas within the greater Yellowstone area (Keane et al. 2011, Halofsky et al. 2017).

In 2010, there was a petition to list whitebark pine under the Endangered Species Act. The U.S. Fish and Wildlife Service conducted a 12-month status review. The finding, published on July 19, 2011 (Federal Register 76[138]: 42631-42654), determined that listing the species under the Endangered Species Act is warranted but precluded by higher priority listing actions. As a result, whitebark pine is a candidate species and the U.S. Fish and Wildlife Service assigned it a listing priority number of 2, indicating the threats are imminent and of high magnitude. This was reduced to priority 8 on December 24, 2015 (Federal Register 80[247]:80586) because the overall magnitude of threat to whitebark pine is somewhat diminished given the current absence of epidemic levels of mountain pine beetle. In August of 2011, the Northern Region designated whitebark pine as a sensitive species (USDA 2011).

The findings in the listing identified interrelated threats to whitebark pine that raises concerns about the long-term viability of whitebark pine ecosystems (USDI 2011). These factors are discussed below; all of these are relevant to the Custer Gallatin National Forest.

- **Fire Suppression:** After a century of suppression, many whitebark stands are experiencing a species conversion to shade-tolerant trees, and a lack of suitable seedbeds for regeneration. The balance of a natural fire regime with related vegetative successive processes has been disrupted, and as a result whitebark pine has lost its competitive advantage (USDI 2011).
- **Climate Change:** The fate of whitebark pine is uncertain because of high uncertainty in regional climate change predictions, the high genetic diversity and resilience of the species, and the localized changes in disturbance regimes and their interactions (Halofsky et al. 2017). In a warmer climate, the species' fundamental habitat may shift to cooler sites at higher elevations and latitudes. Recent studies indicate that whitebark pine is one of the most vulnerable tree species in the northern Rocky Mountains to climate change (Hansen and Phillips 2015). Climate suitability is projected to decline dramatically by the end of the century and the adaptive capacity of whitebark pine is thought to be relatively low because dispersal is fairly limited, it is often outcompeted by other subalpine conifers, and it is highly susceptible to mountain pine beetle and blister rust (ibid). Halofsky et al. (2017) conclude that whitebark pine is not expected to do well under future climates, not because it is poorly-adapted to shifts in climate regimes, but rather because it is currently experiencing major declines from the exotic disease (white-pine blister rust) that preclude its immediate regeneration in future burned areas.
- **White Pine Blister Rust:** White pine blister rust (*Cronartium ribicola*) is an exotic fungal disease against which whitebark has limited resistance. Since blister rust was introduced to North America in 1910, it has spread through most of the range of five-needled pines. As this disease has moved into fragile, high-elevation ecosystems, normal successional pathways have been altered. Because the disease is exotic, these trees have limited defenses. Blister rust typically infects nearly all individuals of the host species, causing branch and stem cankers in trees that eventually kill most trees. In addition to tree mortality, blister rust often kills cone-bearing branches, reducing the reproductive potential of remaining live trees. Halofsky et al. (2017) suggest the WBP has the genetic capacity to overcome both white-pine blister rust and new climates to thrive over the next century, but only with extensive restoration efforts.

- Mountain Pine Beetle: Five-needled pines are susceptible to this aggressive bark beetle. In densely stocked stands, whitebark is more likely to be attacked because of stress from competition. Mountain pine beetle accelerates the loss of key mature cone-bearing trees. Current mountain pine beetle outbreaks are killing more whitebark pine than historical records indicate, and these outbreaks are probably a result of warmer winter temperatures that facilitate expansion of and establishment of beetle populations in the higher-elevation whitebark pine zone (Halofsky et al. 2017)

### *Trend*

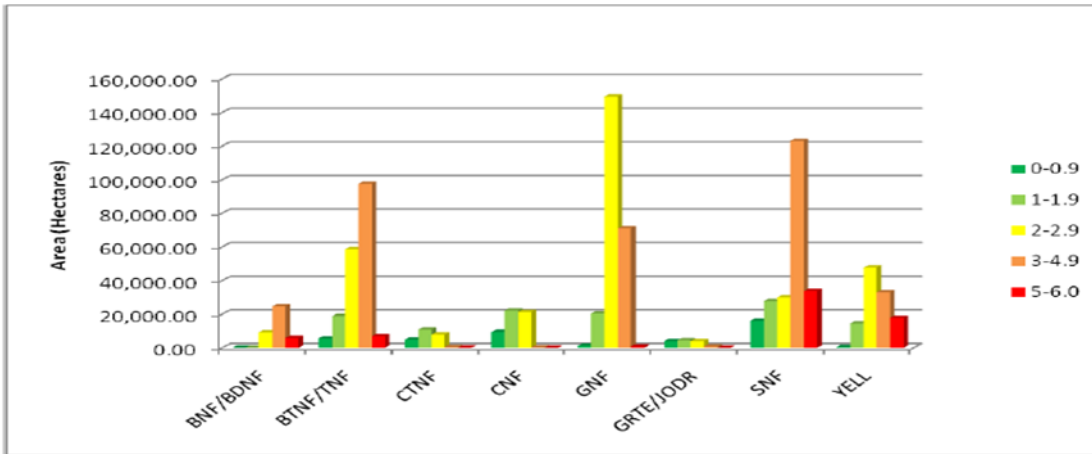
The U.S. Fish and Wildlife Service concluded that there is an ongoing pattern of substantial decline of whitebark pine on the majority of its range (USDI 2011). They predict whitebark pine forests may become severely reduced and its ecosystem functions impacted in the foreseeable future. Analysis at the regional scale indicates that the abundance of live whitebark pine has decreased from 18.3 percent of periodic forest inventory and analysis plots containing at least one live whitebark pine tree, to 15.8 percent in the annualized inventory (USDA 2010). This analysis indicated for the Custer National Forest the numbers were 13.8 percent and 10.0 percent and for the Gallatin 39.3 percent and 28.3 percent (ibid). Those numbers have even further reduced looking at the 2011 mid cycle annualized forest inventory and analysis plots (see “Tree Distribution/Density” section above). Bulk of mortality can be attributed to ongoing mortality from white pine blister rust, wildfire, and the mountain pine beetle (ibid).

Mortality from white pine blister rust primarily occurs in smaller diameter trees and seedlings, however rust incidence is widespread and its severity is increasing. Rust infection rates in the Greater Yellowstone Area are spatially variable and as high as 20 to 30 percent (Greater Yellowstone Whitebark Pine Monitoring Working Group 2016). Surveys in the Greater Yellowstone Area indicate a 20 percent overall infection rate (ibid). Mountain pine beetle mortality in whitebark pine is extensive in the Greater Yellowstone Area and decreasing (ibid). In 2007, satellite imagery indicated that more than 40 percent of WBP stands contained some level of canopy mortality (ibid). In 2008, aerial detection surveys indicated beetle activity in more than 50 percent of whitebark pine stands (ibid). Cone production is reduced in mature trees with blister rust infection due to branch and upper bole mortality. This can have an effect on seedling establishment and understory condition. Preliminary data indicates that understory is present in many stands (ibid). However, it is unknown if this understory will survive to a cone-bearing age. There is also evidence of fires that have burned in the Greater Yellowstone Area between 1946 and 1988 have limited whitebark pine regeneration (ibid).

In 2009, aerial surveys were used with the Landscape Assessment System by Macfarlane and others (2010) to assess mountain pine beetle mortality in the Greater Yellowstone Area. The assessment indicated that more than 50 percent of whitebark pine stands in the Greater Yellowstone Area have already suffered high to complete mortality of mature trees and 95 percent of forest stands containing whitebark pine have measurable mountain pine beetle activity (Macfarlane et al. 2010). The assessment also indicated that the Beaverhead-Deerlodge and Shoshone National Forests had high mortality levels; the Bridger-Teton had high mortality except in portions of the Wind River Range; the Gallatin National Forest had medium to high levels; and the Custer and Caribou-Targhee National Forests and Yellowstone and Grand Teton National Parks showed relatively low mortality levels (see Figure 11).

The loss of whitebark has altered the structure, composition and pattern of high-elevation ecosystems, and threatened their long-term stability and integrity. This impacts hydrological processes and wildlife habitat values, such as grizzly bear food resources. The decline in whitebark pine is expected to

continue into the future. The percentage of whitebark that are resistant to white pine blister rust may increase slowly through the process of natural selection, if five-needled pines are given a chance to regenerate (Tomback et al. 2001). See Insects, Climate, and Ecosystem Diversity sections information on impacts to whitebark pine.



**Figure 11. Mortality rating by administration units: 0-0.9—no unusual mortality; 1-1.9—low mortality; 2-2.9—medium mortality; 3-4—high mortality, and 5-6—residual forest after a major outbreak (Macfarlane et al. 2010)**

In response to the current situation in whitebark ecosystems, the Greater Yellowstone Coordinating Committee's Whitebark Pine Subcommittee, which has worked successfully across boundaries since its inception in 2000, developed this whitebark pine strategy to promote the persistence of whitebark pine over time and space in the Greater Yellowstone Area by: (1) documenting the current condition of whitebark pine in the Greater Yellowstone Area; (2) establishing criteria to prioritize areas for management action; (3) identifying techniques and guidelines to protect and restore whitebark pine; and (4) facilitating communication and distribution of this information. This strategy is intended to enable land management units to maximize the use of their limited resources to maintain the presence of whitebark pine in the Greater Yellowstone Area. The objectives of this strategy include (GYCC 2011):

- Provide a basis for collaboration among the federal land management agencies in the Greater Yellowstone Area to promote effective conservation of whitebark pine across administrative boundaries.
- Protect cone-bearing whitebark pine throughout the Greater Yellowstone Area.
- Maintain and restore the role of whitebark pine in ecosystem function.
- Ensure whitebark pine regeneration and genetic variability through natural and assisted regeneration.
- Promote fire planning and use that protects high-value whitebark pine resources and provides for long-term whitebark pine restoration.

In 2012, Keane and others identified principles of whitebark pine restoration (Keane et al. 2012) that were similar to the Greater Yellowstone Coordinating Committee's strategy and included:

- Promoting rust resistance, by a) supporting selective breeding programs to develop and deploy blister-rust resistant whitebark; b) facilitating and accelerating natural selection for rust resistant

trees by reducing competition, providing openings for natural seed dispersal and seedling survival; and c) planting seedlings from trees known to have some level of resistance.

- Conserving genetic diversity, by collecting seeds and planting genetically diverse seedlings.
- Saving seed sources, by protecting mature seed-producing resistant whitebark pine trees so that apparent rust-resistant seeds can be harvested in the future; and
- Employing restoration treatments, including limiting the spread of blister rust, using fire to encourage regeneration, implementing silvicultural cuttings to reduce competition and increase vigor and reduce likelihood of mountain pine beetle attacks, planting rust-resistant seedlings to accelerate the effects of selection, and promoting natural regeneration and diverse age class structures to maintain ecosystem function and reduce landscape level beetle hazard, and to provide large populations for selection for rust resistance.

The current forest plans do not contain specific standards or guidelines related to maintaining whitebark pine.

### *Information Needs*

Improved mapping and continued ground reconnaissance of the current condition of whitebark pine across the Custer Gallatin National Forest is needed to focus protection and restoration efforts identified in the whitebark pine strategy for the Greater Yellowstone Area. This information will be very helpful for plan implementation but is not critical for the plan revision process.

### **Limber Pine**

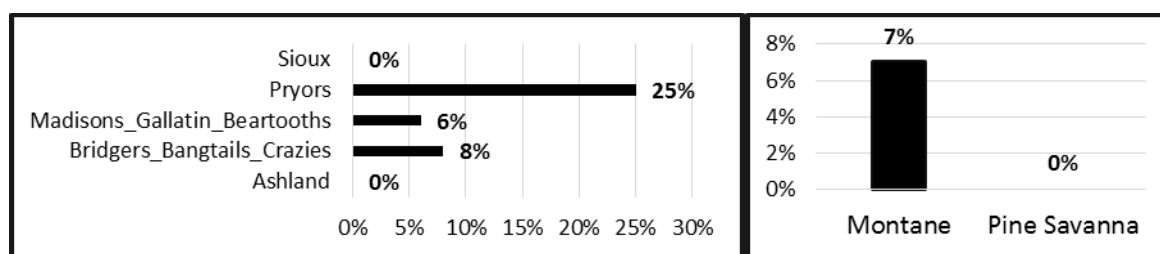
Limber pine is a relatively long-lived, native five-needled pine and is nearly as broadly distributed as whitebark pine, but also occurs at lower timberline and over more arid regions (Keane et al. 2011). It grows across the widest elevational range of any conifer in the Rocky Mountains (Means 2011). On the Custer Gallatin National Forest (montane unit) it occurs at both lower and upper treeline and as individuals or in patchy stands at all elevations. In the lower timberline it occurs as ecotones between the sage/grass and forest/woodlands with expansion and contraction due to dynamic relationships among vegetation, climate, and wildland fire (ibid). Frequent fire disturbance regimes likely occurred in the lower treeline limber pine and mixed to high severity fires in the mid to upper elevation much like fire histories of whitebark pine (ibid). Restablishment is facilitated by Clark's nutcracker (ibid).

Limber pine is a shade-intolerant, early seral to pioneer species and is very tolerant to drought, thus it is able to establish and grow in some of the most arid environments (USDA 2015b). On the Custer Gallatin National Forest, it is often associated with Douglas-fir, ponderosa pine, and sometimes aspen in the lower timberline areas. On upland and high elevation sites, it can be often found on limestone substrates and droughty soils, and associated with lodgepole pine, subalpine fir, Engelmann spruce and whitebark pine. It competes poorly with other encroaching species on mesic sites and is often succeeded by Douglas-fir and subalpine fir (ibid). It is easily killed by fire and before fire suppression was likely found persisting in fire-protected areas that experienced rare fires of low severity (rocky outcrops, barren areas and moist north slopes).

This species has marginal timber value and is important for watershed stability, wildlife food and cover and tends to grow on sites too harsh for other conifer species (Jackson et al. 2010). It is susceptible to damage from wildland fire, white-pine blister rust, red belt, and is experiencing mortality from mountain pine beetle (Jackson et al. 2010, USDA 2015b, Means 2011). Blister rust has been present in limber pine

in Montana for over half a century (Jackson et al. 2010). Across the Northern Region these stressors are adding to the decline of limber pine (USDA 2015b).

Limber pine does not occur on the pine savanna unit. Forest inventory and analysis indicates limber pine is present on about 7 percent (approximately 155,800 acres) of the montane unit of the Custer Gallatin National Forest. The Pryors unit has the largest percent of its area where limber pine is present and is estimated at about 25 percent (approximately 17,426 acres), however being the smallest unit it has the smallest acreage of limber pine. Due to the small amount of forest inventory and analysis plots the 90 percent confidence interval around this estimate is wide, between 4,700 and 31,300 acres. Seventy three percent of the limber pine in the Pryors is 5 inches or larger. About 8 percent (approximately 15,600 acres) of the Bridgers Bangtails Crazies unit has limber pine present and 65 percent is below 5 inches. The Madison, Henrys Lake, Gallatin, Absaroka and Beartooth Mountains unit is the largest in size with about 6 percent (approximately 121,400 acres) with limber pine present and the the less than 5 and the greater than or equal to 5 inch are nearly equally represented. See Figure 12 below and Table 60 in the Appendix A.



**Figure 12. Presence of limber pine by proportion of analysis area and ecological unit, R1 summary database, forest inventory and analysis plots**

### *Trend*

Chronic injury and mortality from white pine blister rust in conjunction with mountain pine beetle outbreaks has recently spurred heightened concern for the future of limber pine throughout its range (Jackson et al. 2010). Recent data from Montana indicates an overall infection rate of 50 percent, although severity is low (Burns et al. 2012).

Limber pine is a shade intolerant species and generally is the first conifer to establish recently disturbed sites (ibid). Lower tree line communities (semi-arid sites) are predicted to be particularly vulnerable to climate change (Means 2011). The lower tree line limber pine generally has a different set of management pressures than the upper tree line limber and whitebark pines (ibid). At the higher elevations, insect and disease, fire exclusion, visual resources, wildlife habitat, and climate change issues are of concern. The lower tree line limber pine not only have these issues, but also have issues related to livestock grazing, fuels management and energy development (ibid). They also entail management of a different set of wildlife species.

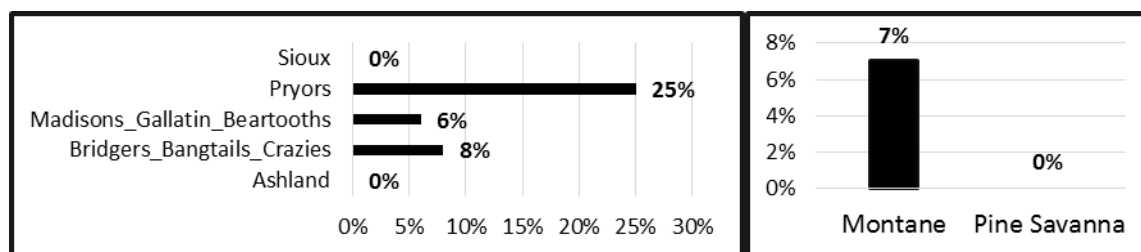
Disturbance interactions with warming climate will likely be important to future limber pine dynamics. Some anticipate that warming temperatures on the east side of the Northern Region, along with increasing but more variable precipitation, especially during the growing season, and waning snowpack will result in increased growth in many limber pine communities (USDA 2015b). Warm temperatures, even with increased precipitation, could also result in drier conditions, especially for seed germination and seedling growth (ibid). Some believe that while isolation and climate conditions of limber pine communities may have provided some protection in the past, lower tree line areas are just as, or more,

susceptible to white pine blister rust and mountain pine beetle (Means 2011). Alterations of natural fire regimes can have an influence on the abundance and health of limber pine. Fire exclusion has likely expanded limber pines range into areas historically restricted by fire. These newly established limber pine communities across the NR are experiencing dramatic declines due to white-pine blister rust, mountain pine beetles, and red belt (Jackson et al. 2010, USDA 2015b). Mountain pine beetle mortality of the seed producing individuals can have an impact for reestablishment as it takes up to 50 years for limber pine to produce cone (Klutsch et al. 2011). This reduction combined with the stresses of blister rust, competition, and climate change could further decline limber pine communities (ibid).

The International Union of Nature identified limber pine with a “least concern” and the Nature Serve gave it a “secure” rating for five needle pines in the U.S. (Keane et al. 2011). This species is moderately vulnerable to climate change based on its high tolerance to drought and ability to populate severe environments, but high susceptibility to the introduced white-pine blister rust and fire damage may put this species in peril (USDA 2015b).

### Information Needs

Limited research has been done on limber pine as it relates to genetics, ecological roles, and predictive models based on climate change (Means 2011). Additional research is needed in this area but is not immediately critical for the plan revision process.



**Figure 13. Presence of limber pine by proportion of analysis area and ecological unit, R1 summary database, forest inventory and analysis plots**

### Tree Distribution/Density

Cover types discussed previously are groupings of dominant vegetation. As succession and disturbances occur species may be present or absent across multiple cover types. In our montane unit within the ponderosa pine cover types, Douglas-fir may be the dominant species present in the absence of fire or Douglas-fir, spruce, or subalpine fir may be the dominant species in lodgepole cover types during later successional stages. In our pine savanna landscapes, ponderosa pine may be absent for periods of time on potential ponderosa pine cover types, due to large disturbances that have removed the seed source to reestablish. Tree distribution and density has been determined as important for understanding ecosystem diversity and function across our Custer Gallatin National Forest landscapes (key ecosystem characteristic – Table 1). Forest inventory and analysis data was used to measure the presence of species and trees per acre by diameter classes. Figure 14 and Figure 15 below summarize the presence of individual species and proportion of the landscapes. Appendix A contains a table summarizing presence of individual tree species by trees per acre by size class for the analysis areas.

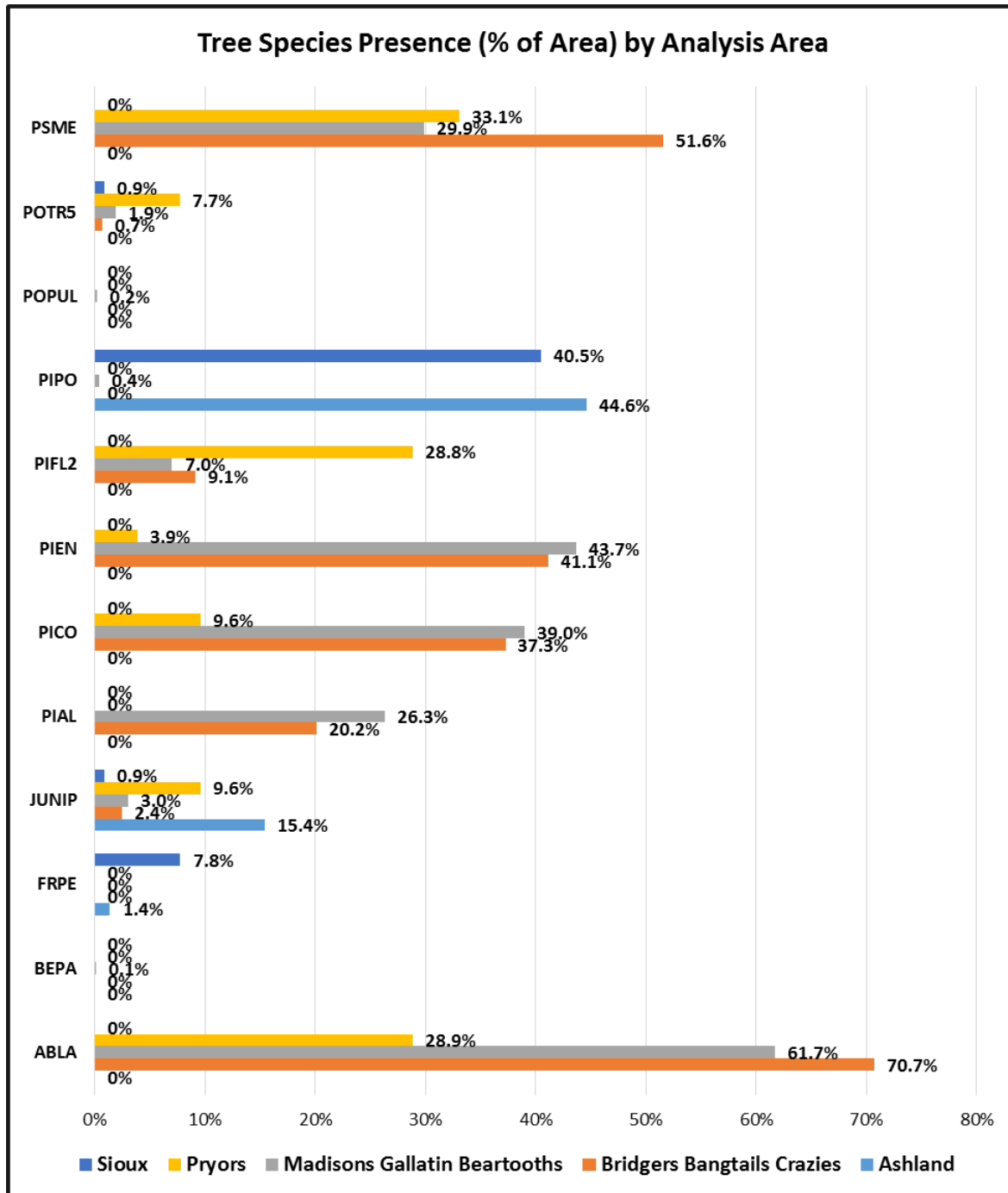
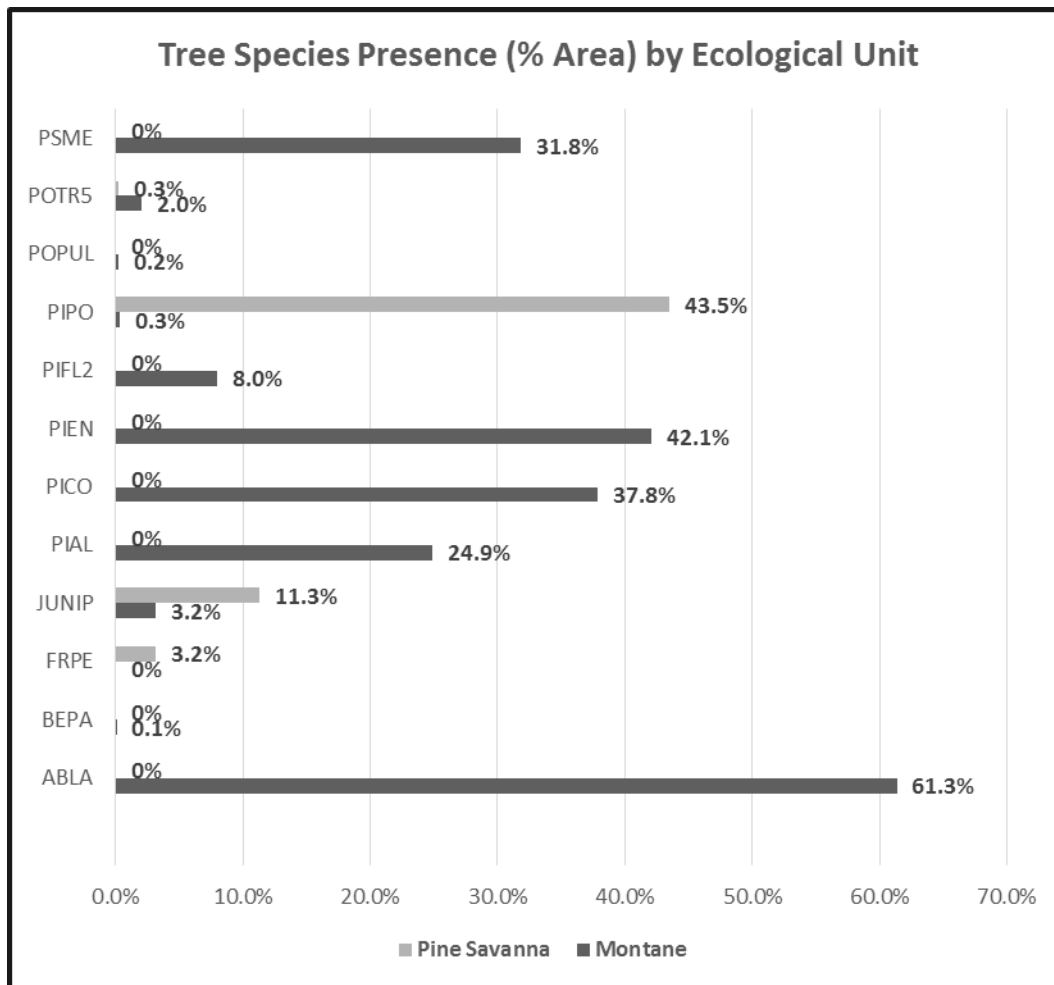


Figure 14. Proportion of tree species presence by analysis area, R1 summary database, forest inventory and analysis plots





**Figure 15. Proportion of tree species presence by ecological unit, R1 summary database, forest inventory and analysis plots**

### Madison, Henrys Lake, Gallatin, Absaroka and Beartooth Mountains

Subalpine fir, spruce, Douglas-fir, whitebark and lodgepole pine are estimated to be the dominant species present as indicated previously by the cover types. Estimated aspen (1.9 percent) presence is relatively rare and mainly less than 5 inches in diameter at breast height with largest size less than 14.9 inches. Ponderosa pine (0.4 percent), cottonwood (0.2 percent), and paper birch (0.1 percent) have a limited presence on the landscape. Subalpine fir has the most dominant presence (61.2 percent) and is represented nearly equally with trees smaller than 5 inches in diameter at breast height and greater than or equal to 5 inches in diameter at breast height. Largest trees are less than 19.9 inches in diameter at breast height. Spruce (43.7 percent) is most abundant in the greater than or equal to 5 inches class with a presence of 25 inches plus diameter at breast height class. Lodgepole pine (39 percent) dominated by 5 inches plus and largest presence less than 24.9 inches. Douglas-fir (29.8 percent) is most dominant in the greater than or equal to 5 inches class with a presence of 25 inches plus diameter at breast height. Whitebark pine (26.3 percent) is nearly equally represented in the less than 5 inches and greater than or equal to 5 inches class, with largest presence less than 24.9 inches in diameter at breast height. Limber pine (7 percent) is not well represented and nearly equal in both size classes with largest less than 19.9 inches. Juniper (3 percent) not well represented mainly in the greater than or equal to 5 inches size and less than 14.9 inches.

### **Bridger, Bangtail, and Crazy Mountains**

This landscape is similar for presence of tree species except that ponderosa pine, cottonwood, and paper birch are absent. Subalpine fir (70.4 percent), Douglas-fir (51.6 percent), spruce (41.1 percent), lodgepole (37.3 percent), and whitebark pine (20.2 percent) are the species most commonly present. Douglas-fir is present more than in the previous landscape discussion and whitebark pine less. Similar size class dominance and largest trees occur by species. Subalpine fir is most abundant in the less than 5 inches size and the largest tree present is less than 24.9 inches. Douglas-fir, spruce, and lodgepole pine are represented more in the greater than or equal to 5 inches size class and largest sampled was greater than 25 inches. Whitebark pine is most represented in the greater than or equal to 5 inches class and less than 15 inches. Juniper (2.4 percent) and limber pine (9.1 percent) presence are less common. Juniper mainly occurs in the greater than or equal to 5 inches class and limber less than 5 inches both up to 14.9 inches. Aspen (0.07 percent) presence is rare on the landscape and in the less than 5 inches size class.

### **Pryor Mountains**

This landscape is dominated by non-forested cover types (51 percent), thus a difference in species presence and at a much smaller representation of the area. Douglas-fir (33.1 percent), subalpine fir (28.9 percent), and limber pine (28.8 percent) are the most common species present. Lodgepole pine (9.6 percent), juniper (9.6 percent), aspen (7.7 percent), and spruce (3.9 percent) are less commonly present. Whitebark pine does not occur. Although ponderosa pine was not sampled, it is known to have a minor presence on the landscape. Because of its rare occurrence, intensification of the forest inventory and analysis plots would need to occur to capture its presence. Douglas-fir is most represented in the greater than or equal to 5 inches size and largest tree sampled is greater than 25 inches. Limber pine, spruce, and juniper are only represented in the greater than or equal to 5 inches size. Largest diameter in limber pine is less than 15 inches, juniper is less than 24.9 inches, and spruce is greater than or equal to 25 inches. Subalpine fir, limber pine, and aspen are represented in both size classes; subalpine fir and lodgepole pine up to 20 inches and aspen up to 15 inches.

Collectively the montane unit have the same general species presence. Subalpine fir (61 percent), spruce (42 percent), lodgepole pine (37.8 percent), Douglas-fir (31.8 percent), and whitebark pine (24.9 percent) are commonly present. Limber pine (8 percent) and juniper (3.2 percent) are less common. Aspen, ponderosa pine, cottonwood, and paper birch have a rare presence.

### **Ashland District**

Ponderosa pine is estimated to be present on 44.6 percent of the area with dominance of the greater than or equal to 5 inches size class and largest tree sampled greater than 25 inches. Juniper is present on 15.4 percent of the area with most presence in the greater than or equal to 5 inches class and with trees sampled larger than 25 inches. Aspen was not sampled but is known to occur in very small areas on the district. Green ash was estimated to be present on 1.4 percent of the area equally in both size classes, with individuals sampled greater than 25 inches.

### **Sioux District**

Ponderosa pine is estimated to be present on 40.5 percent of the area with dominance of the greater than or equal to 5 inches size class and largest tree sampled greater than 25 inches. Juniper and aspen are estimated at 0.9 percent of the area with presence in the less than 5 inches class. Green ash was estimated to be present on 7.8 percent of the area equally in both size classes, with individuals sampled

less than 19.9 inches. Although not sampled, paper birch is known to occur in isolated small areas in the Chalk Buttes, Long Pines, and Slim Buttes.

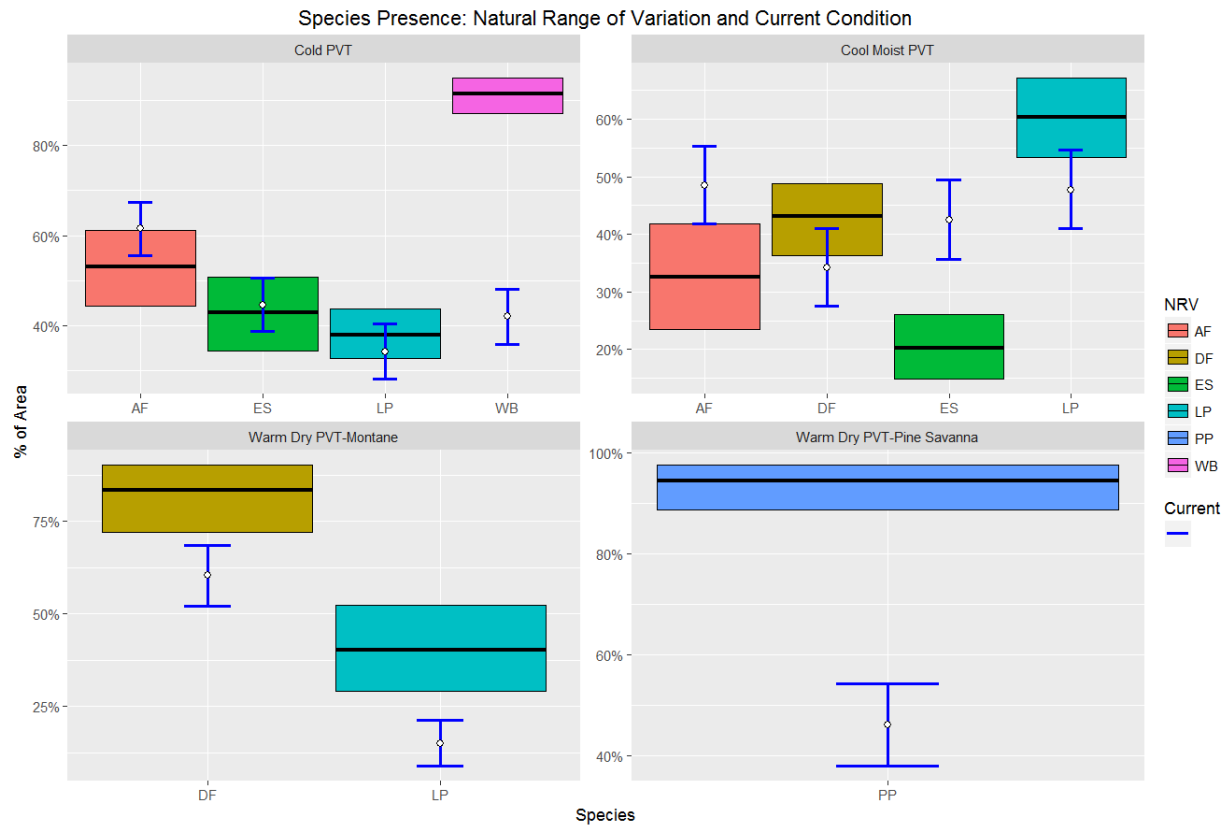
The pine savanna unit is currently dominated by a non-forested cover type (70 percent). Collectively estimated presence of ponderosa pine is 43.5 percent, juniper is 11.3 percent, green ash is 3.2 percent, and aspen is 0.3 percent of the area.

## Trend

See trend section for Lifeform and Cover Type.

### Tree Species Presence – Natural Range of Variation

The SIMPPLLE landscape dynamics simulation model was used to estimate the natural range of variation for tree species presence across the Custer Gallatin National Forest. Comparing the Natural Range of Variation to the current condition provides important information regarding the ecological integrity of this key ecosystem characteristic. Figure 16 displays the results of the Natural Range of Variation analysis for tree species presence. Results have been grouped by the Region 1 Broad Potential Vegetation Types (PVTs; Milburn et. al 2015).



**Figure 16. The Natural Range of Variability (NRV) for tree species presence within the three forested Region 1 Broad Potential Vegetation Type groups found on the Custer Gallatin National Forest. The Warm Dry Potential Vegetation Type has been split between the Pine Savanna and Montane geographic areas. The mean (horizontal black bars) and 90 percentile range (colored blocks) of the simulated Natural Range of Variation for presence are shown for common species including subalpine fir (AF), Engelmann spruce (ES), lodgepole pine (LP), whitebark pine (WB), Douglas fir (DF), and ponderosa pine (PP). Forest Inventory and Analysis data was also used to estimate the mean (white dots) and 95% confidence interval (blue bars) of the current conditions.**

The SIMPPLLE natural range of variability analysis shows that in the Cold Forest, whitebark pine is significantly below historic levels, primarily due to the devastating effects of blister rust and pine beetles as discussed above. In Cool Moist Forest, shade tolerant species such as Engelmann spruce and subalpine fir have become over represented relative to the natural range of variation while less tolerant species such as Douglas fir and lodge pole pine have become less common. In the pine savanna, the geographical distribution of ponderosa pine is significantly less than the natural range of variability, possibly due to widespread, severe wildfires removing both existing trees and seed source from large areas.

## Structure

This broad to mid-scale analysis uses the Region 1 classification system and tools in the forest inventory and analysis summary data base to describe the key ecosystem characteristics for structure and function. Hazards for the identified indicator insects are discussed in the stressors and drivers section of this report. Connectivity uses the current vegetation layer for the forest (Region 1 existing vegetation database) to get at stand replacing disturbance pattern and for forest horizontal structure SIMPPLLE will be used.

Key ecosystem characteristics as it relates to structure that were identified for the Custer Gallatin National Forest include: Forested size class, large live trees, forested vertical structure, forested canopy density class, dead trees, large woody debris, and old growth. A discussion of existing conditions of these key ecosystem characteristic indicators and measures follows.

## Forested Tree Size Class

For simplicity, this analysis uses tree diameter to depict tree size using a 5 inch diameter break to assign five general tree size classes: seedling/sapling, small tree, medium tree, large tree, and very large tree. These classes represent where the dominant size occurs; however, individuals or small numbers of other sized trees not within the size class may still be present. Presence of large trees has been identified as an indicator for structure as it relates to large live trees and will be discussed separately later outside of these diameter classes.

A correlation between diameter (size) of a tree and age is variable. Not always are large trees old; this may be a function of how many individual trees are in an area that compete for resources that allow them to grow and increase diameter. However, conclusions can generally be drawn about successional stages as described in Table 7 below. Following the table is a discussion by the defined landscape areas and the identified measure of percent of the area these five size classes occur.

**Table 7. Tree size classes**

<b>Tree Size Class</b>	<b>Description</b>
Seedling/Sapling	Forest inventory and analysis plot averages less than 5 inches diameter. Due to small tree size and crown widths, usually ample sunlight is able to reach the forest floor and abundant grasses, forbs, and shrubs are a dominant feature. When summarizing Region 1 existing vegetation data, transitional areas are also included in this size class. In the ponderosa pine forest types on the pine savanna landscapes, ponderosa pine seedlings establish many times in a clumpy nature, sometimes over extended periods.
Small Tree	Forest inventory and analysis plot averages 5 to 9.9 inches diameter. Usually limited sunlight reaches the forest floor and shade tolerant understory grasses, forbs, and shrubs may dominate. In more open forests, early successional, shade intolerant understory plants can persist. In ponderosa pine cover types in pine savanna landscapes, trees establish in a clumpy condition and areas fill in individuals, thus in some cases multiple sizes.

Tree Size Class	Description
Medium Tree	Forest inventory and analysis plot averages 11 to 14.9 inches diameter. As with the small tree class, usually the more shade tolerant plants will dominate forest floor vegetation based on typical density. As with small trees in the ponderosa pine types on the pine savanna landscapes, ponderosa pine seedlings will develop in small openings or when small disturbances occur. This creates many times more than one story of ponderosa pine.
Large Tree	Forest inventory and analysis plot averages 15-19.9 inches diameter. Shade tolerant vegetation usually dominates in the undergrowth. This class usually represents the late successional forest condition. Like in the medium size class, ponderosa pine types on the pine savanna landscapes will have ponderosa in the understory.
Very Large Tree	Forest inventory and analysis plot averages greater than 20 inches diameter. This size class is rare due to productivity and disturbance regimes found on the Custer Gallatin National Forest. Shade tolerant vegetation usually dominates in the undergrowth in the montane landscapes. This class usually represents the late successional forest condition. On the pine savanna landscape very large trees are uncommon and when present are in very small numbers/clumps. Understories on the pine savanna landscapes contain ponderosa pine.

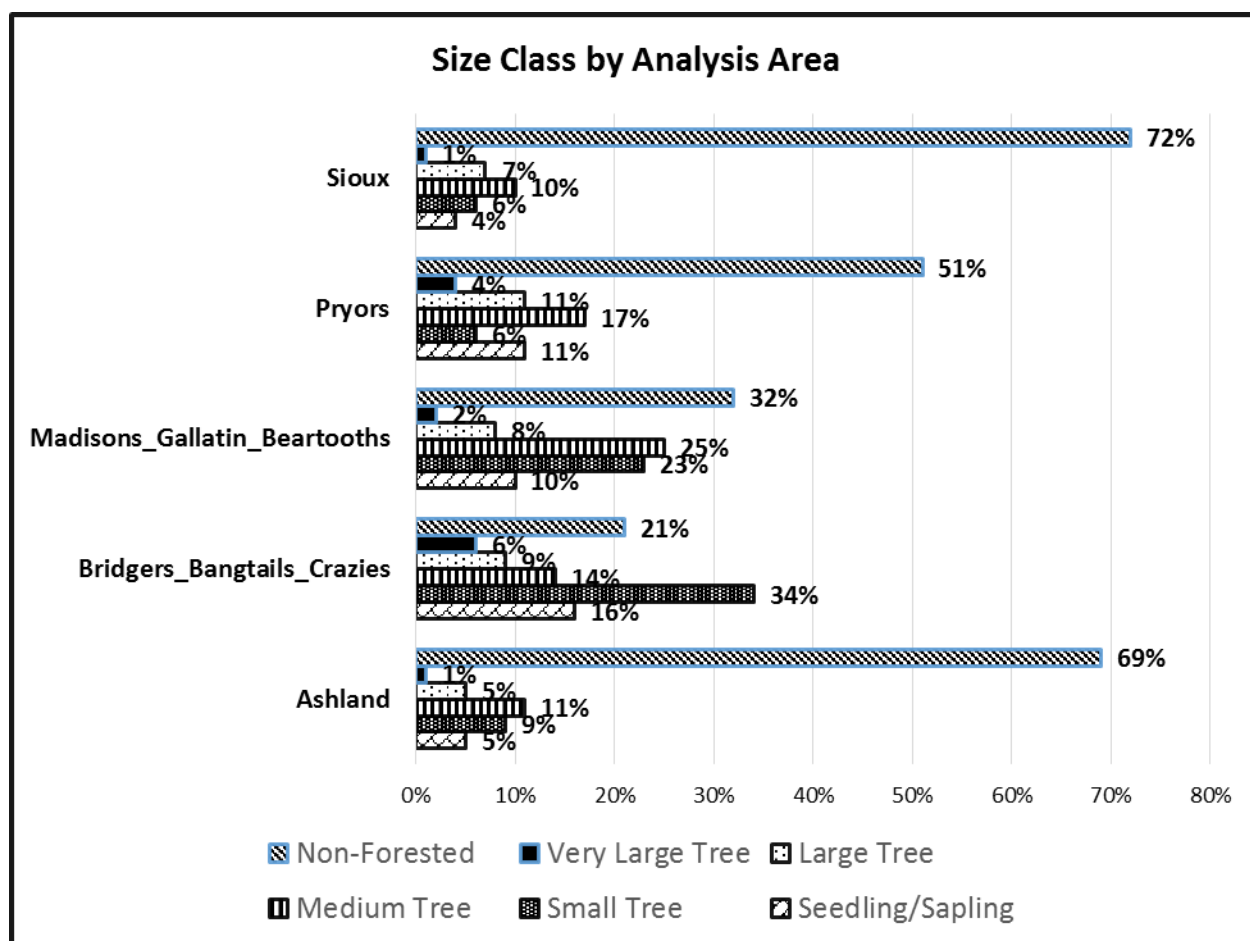


Figure 17. Size class by proportion of analysis area, R1 summary database, forest inventory and analysis plots

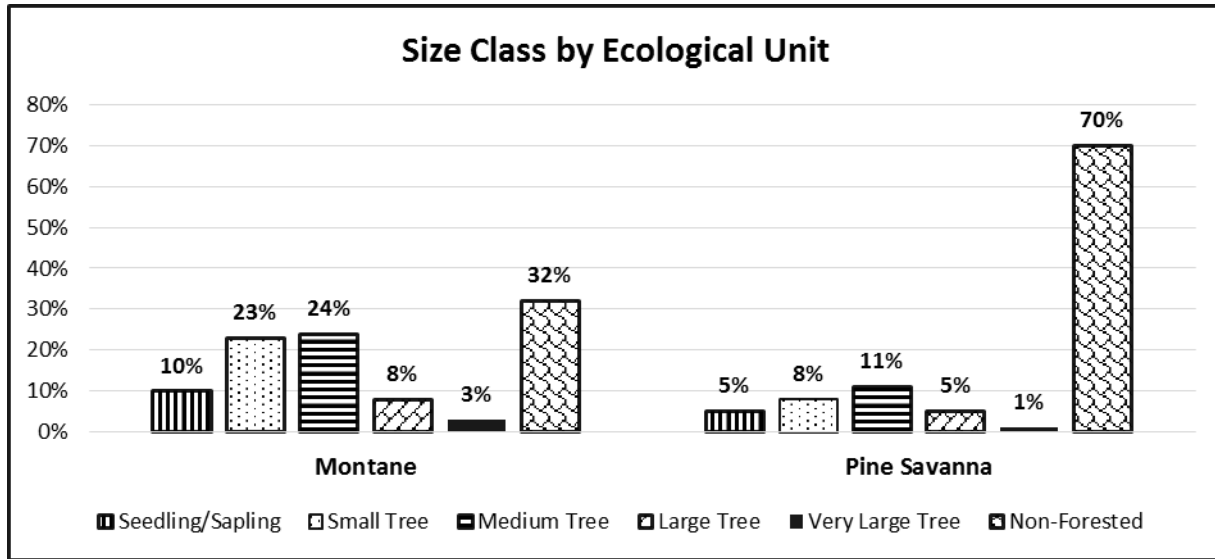


Figure 18. Size class by proportion of ecological unit, R1 summary database, forest inventory and analysis plots

#### *Madison, Henrys Lake, Gallatin, Absaroka, and Beartooth Mountains*

Small and medium size classes are approximately equal in abundance and represent 48 percent of the area. The seedling/sapling size class represents 10 percent and the large class represents 8 percent. The very large class is 2 percent of the area.

#### *Bridger, Bangtail, and Crazy Mountains*

The small size class is most abundant in the existing forest cover at 34 percent of the area. Seedling/sapling class represents 16 percent followed by 14 percent in the medium class. Large size class is at 9 percent and very large has the highest representation of the montane unit at 6 percent.

#### *Pryor Mountains*

The Pryor landscape is the least forested of the montane unit. Medium size class is most abundant at 17 percent, followed by seedling/sapling and large size both at 11 percent. Small size is dominate on 6 percent and very large on 4 percent. Collectively these montane units are dominated by small and medium size classes (23 percent and 24 percent). Seedling/sapling is next highest in abundance at 10 percent, followed by large at 8 percent and very large at 3 percent.

#### *Ashland District*

Medium size is the most abundant at 17 percent, followed by seed/sapling and large classes at 11 percent. The small sized tree class is represented on 6 percent and the very large on 4 percent of the landscape.

#### *Sioux District*

Like the Ashland landscape the medium size class is most abundant (10 percent). The large size class is represented on 7 percent and the small size class on 6 percent of the area. Seedling/sapling is represented on 4 percent, while the very large class is uncommon at 1 percent of the area. Collectively the pine savanna units are dominated by the medium sized tree class, followed by the small sized class. The very large class is uncommon and is estimated at only 1 percent of the landscape area. Seedling/sapling and large size classes are both represented on 5 percent each, on the landscape.

### *Trends*

Individual trees growth in the forest based on the productivity of the site, the amount of precipitation, insect and disease activity that reduces growth, individual species growth traits, and the degree of competition for light, water and nutrients. Short lived species such as lodgepole pine generally do not get larger than the small or medium class, unless small scale natural disturbances take place or vegetative treatments occur in younger ages. These events reduce competition which allows increased diameter growth. Longer lived species like Douglas-fir, ponderosa pine, and whitebark pine are capable of growing to the larger size classes if open growing conditions are maintained by small disturbance events or vegetation treatments that reduce competition for growth necessities (water, nutrients, and light). Where fires have been suppressed and no other large scale disturbances have taken place in existing mid aged to older aged stands progression of existing size classed into larger size classes will be slow. In areas where small scale disturbances have taken place or vegetation thinning treatments have occurred this progression may be more rapid.

Fire suppression on the Custer Gallatin National Forest landscapes can potentially have two effects on size class; reduction in the amount of the seedling and sapling size class that would have been created by stand replacement fire and a decrease in potential large and very large size class by promoting high tree densities that suppress individual tree growth. These two effects are likely the result of the dominance of the small and medium size classes across all the analysis areas. However, in the future there will be an increase in the seedling/sapling size class as the large wildfires over the last 16 years reestablish with forest cover. Sites with an adequate seed source or those sites that are planted will add acres to this class much sooner than sites that do not have a nearby seed source.

### **Large Live Trees**

Large live trees (greater than or equal to 15 inches in diameter at breast height) is a key ecosystem characteristic chosen to describe structure within the forested ecosystems. Large live trees are important for many reasons and understanding the existing conditions of how many of these may exist can further understand the diversity across the forest. FIA data was used to determine large live trees per acre, basal area per acre, and the percent of how many sampled plots had a presence of 15 inches and larger live trees.

Basal area is a common term used to describe the average amount of an area (usually an acre) occupied by tree stems. It is defined as the total cross-sectional area of stems in a stand measured at breast height (4.5 feet above ground). The basal area of trees in a given land area describes the degree to which an area is occupied by trees and is generally expressed in square feet per acre (square feet per acre). Basal area is useful in determining various resource management needs (that is, wildlife habitat, viability of timber harvest activities, etc.). Following Figure 19, Figure 20, and Figure 21 are discussions on these measures of large live trees across the analysis areas and ecosystems.

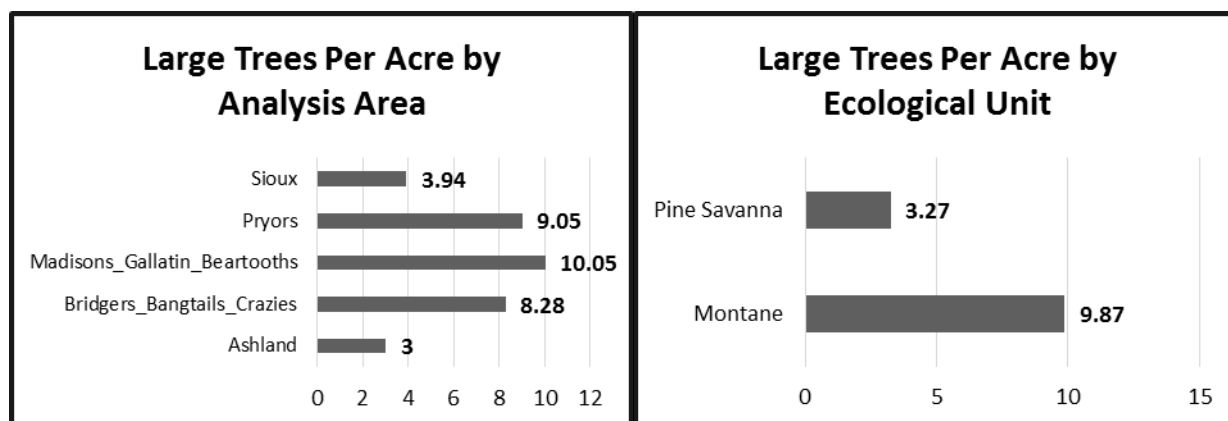


Figure 19. Estimates of greater than 15 inches diameter at breast height (DBH) trees per acres by analysis area and ecological unit, R1 summary database, forest inventory and analysis plots

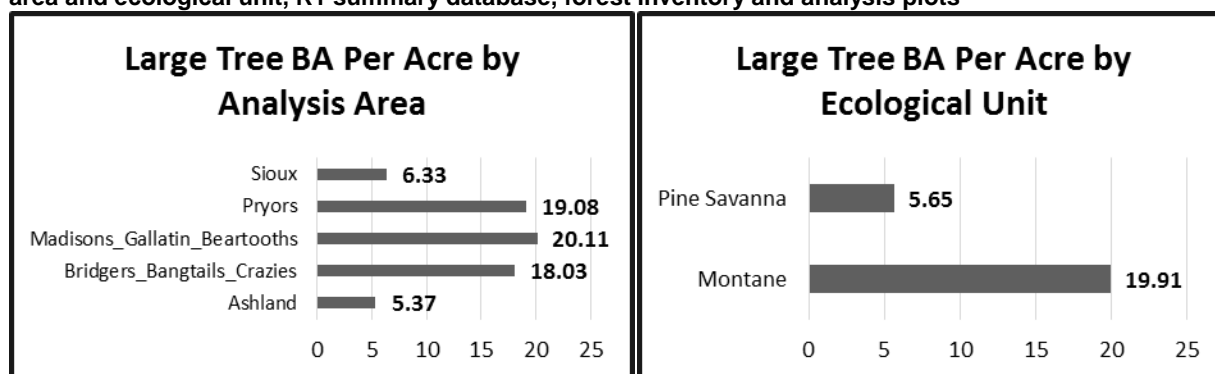


Figure 20. Estimates of greater than or equal to 15 inches diameter at breast height (DBH) basal area per acres by analysis area and ecological unit, R1 summary database, forest inventory and analysis plots

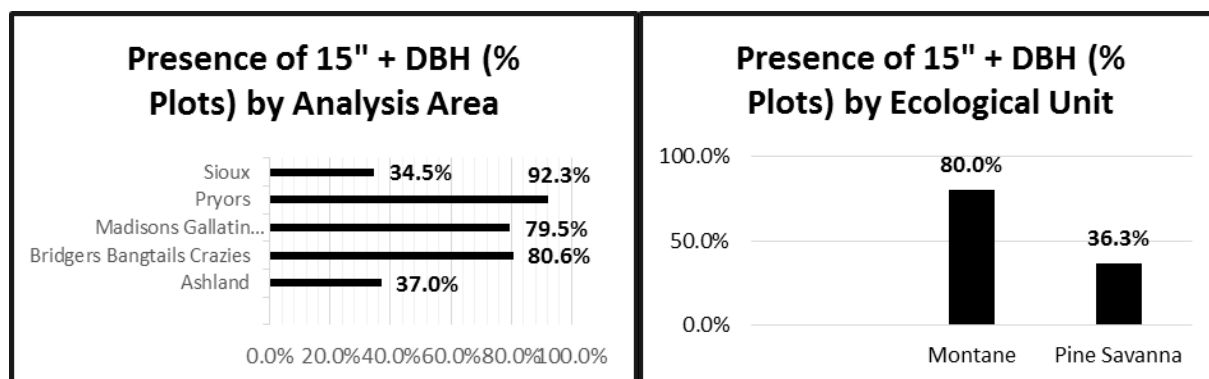


Figure 21. Percent of plots by analysis area and ecological unit with presence of greater than or equal to 15 inches diameter at breast height (DBH) trees, R1 summary database, forest inventory and analysis plots

#### Madison, Henrys Lake, Gallatin, Absaroka, and Beartooth Mountains

This landscape has the highest estimated average number of large live trees and basal area per acre greater than or equal to 15 inches in diameter at breast height (10 trees per acre and 20 square feet per acre). Seventy nine percent of the plots sampled had presence of 15 inch and larger trees.



### *Bridger, Bangtail, and Crazy Mountains*

Approximately 81 percent of the sampled plots had an average of trees 15 inches and larger. Average large live trees per acre is estimated at 8 with 18 square feet per acre.

### *Pryor Mountains*

Pryor's had the second highest amount of average large live trees at 9 trees per acre with 19 square feet per acre. Ninety two percent of the plots sampled had presence of large live trees. Collectively these montane units have an estimated higher number of large live trees per acre than the far eastern pine savanna unit (5.75 trees per acre versus 3.25 trees per acre). Eighty percent of the sampled plots across the montane unit had a presence of 15 inches and larger live trees.

### *Ashland District*

This ponderosa pine forest landscape has an average of 3 large live trees per acre with 5 square feet per acre of basal area. Thirty seven percent of the sampled plots had a presence of trees 15 inches and larger.

### *Sioux District*

The Sioux landscape has slightly higher average live trees per acre and basal area per acre than the Ashland landscape (3.94 trees per acre and 6.33 square feet per acre). And slightly lower percent of the sampled plots (34.5 percent) had presence of live trees 15 inches and larger. Collectively the pine savanna units have fewer average large live trees per acre in comparison to the montane units.

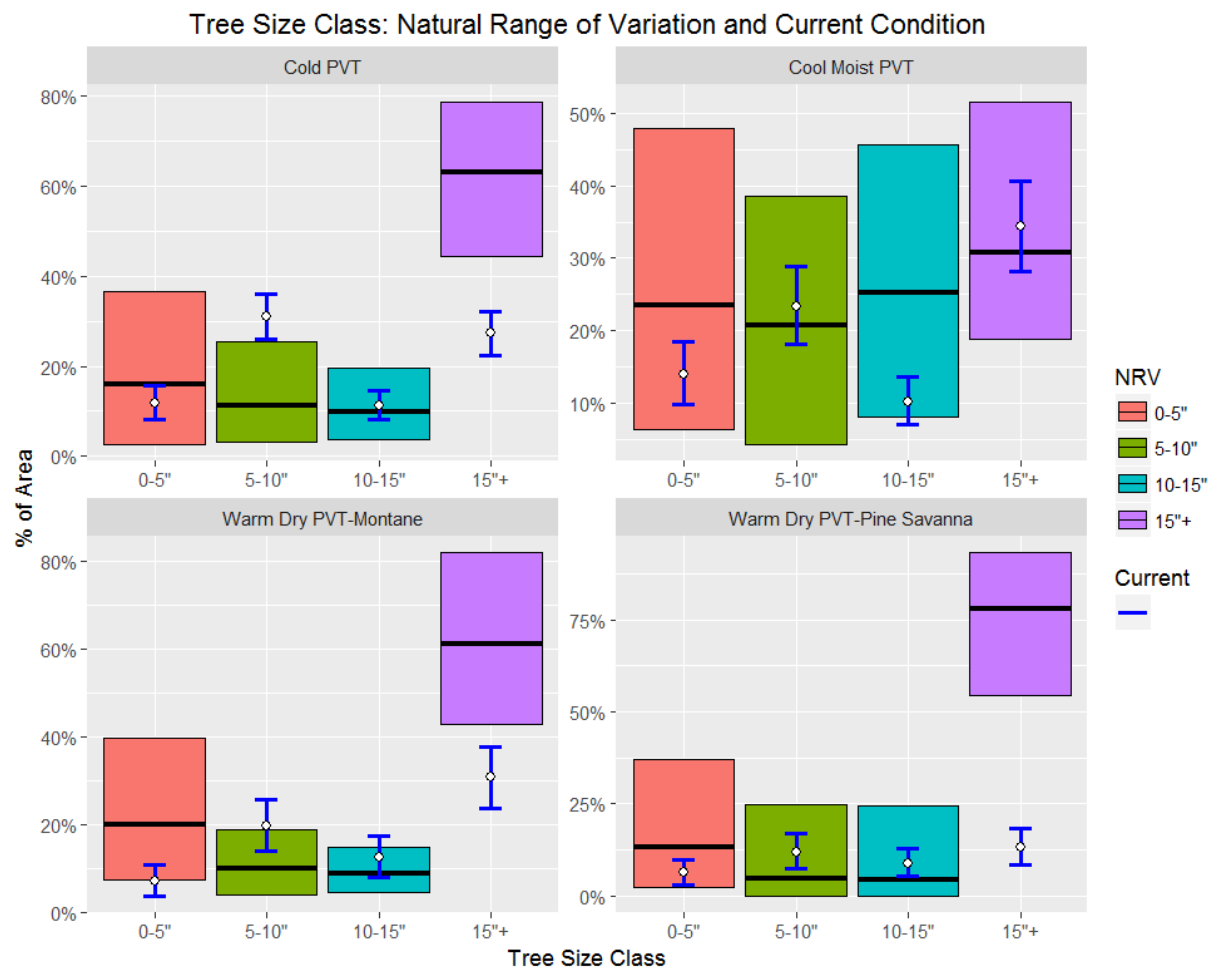
### *Trends*

See trend for size class. Individual tree growth and the ability to grow to large sizes is influenced by many factors: site conditions (e.g. soil characteristics including productivity, precipitation amounts), insects and disease activity that hinders growth potential, growth traits of individual species, disturbances, and more importantly the degree of competition for light, nutrients, and water between trees on a particular growing site. When frequent disturbance or vegetation management maintain lower stand densities competition for growth resources (light, nutrients, and water) decreases and large trees may develop. Patches of landscapes that are protected from disturbance, can promote large tree development. These patches commonly described as refugia are generally associated with sites that have more moisture available. An example of this is on the pine savanna ecosystem unit. Large tree are more common in draws or depressions where water tables tend to be higher which support tree growth.

Reductions of large trees likely occurred historically as early settlers extracted trees for mining timbers, railroad ties, home building, and other needs. Competition decreases tree vigor and makes trees more susceptible to beetle attack. Larger trees are generally attacked first as seen in recent beetle mortality in the high elevation large whitebark pine in the Pickett Pin and Hellroaring plateau areas and in large spruce trees in Main Canyon on the Beartooth District (Egan 2010, 2011, 2012, 2013). Additionally, stand replacement fires may reduce large trees. In high frequency, low intensity fire regimes, species like ponderosa pine are adapted to fire, but with fire exclusion large stand replacement fires are occurring. On the pine savanna unit, the acreage of stand replacement fire since 1988 has increased and has resulted in mortality of large trees. Pine engraver beetle populations increases dramatically post fire on the pine savanna unit. Fire damaged individual large ponderosa pine that appear to have survived the fire disturbance are commonly attacked and killed by this beetle.

### Tree Size Class – Natural Range of Variation

The SIMPPLLE landscape dynamics simulation model was used to estimate the Natural Range of Variation of tree size classes across the Custer Gallatin National Forest. Comparing the Natural Range of Variation to the current condition provides important information regarding the ecological integrity of this key ecosystem characteristics. Figure 22 displays the results of the Natural Range of Variation analysis for tree size class. Results have been grouped by the Region 1 Broad Potential Vegetation Types (PVTs; Milburn et. al 2015).



**Figure 22. The Natural Range of Variability (NRV) for tree size class within the three forested Region 1 Broad Potential Vegetation Type groups found on the Custer Gallatin National Forest. The Warm Dry Potential Vegetation Type has been split between the Pine Savanna and Montane geographic areas. The mean (horizontal black bars) and 90 percentile range (colored blocks) of the simulated Natural Range of Variation are shown. Forest Inventory and Analysis (FIA) data was also used to estimate the mean (white dots) and 95% confidence interval (blue bars) of the current conditions. Note: FIA plots with less than 20 square feet of basal area and less than 100 trees per acre are not assigned a size class. There are numerous recently burned plots, particularly in the Warm Dry Potential Vegetation Type, that would fall in to this category. Consequently, the total area of current conditions represented by these size classes may not equal 100%.**

In the Cold Potential Vegetation Type, there is an excess of pole size trees but a deficit of large trees relative to the Natural Range of Variation. Given that most of this Potential Vegetation Type is in protected areas with little active management, this is likely due to the combined effects of mountain pine beetle and blister rust on white bark pine trees. The Warm Dry Potential Vegetation Type also

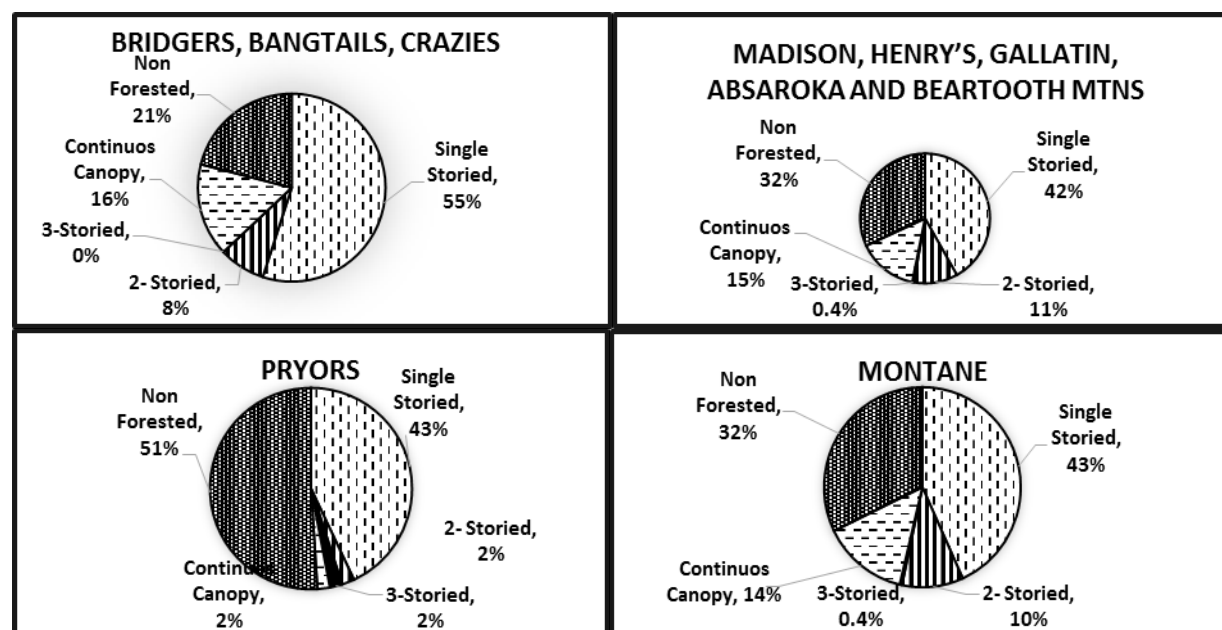
shows a deficit of large trees, perhaps due to the effects of historic logging as well as a legacy of fire suppression often resulting in stands with a high density of slow growing trees.

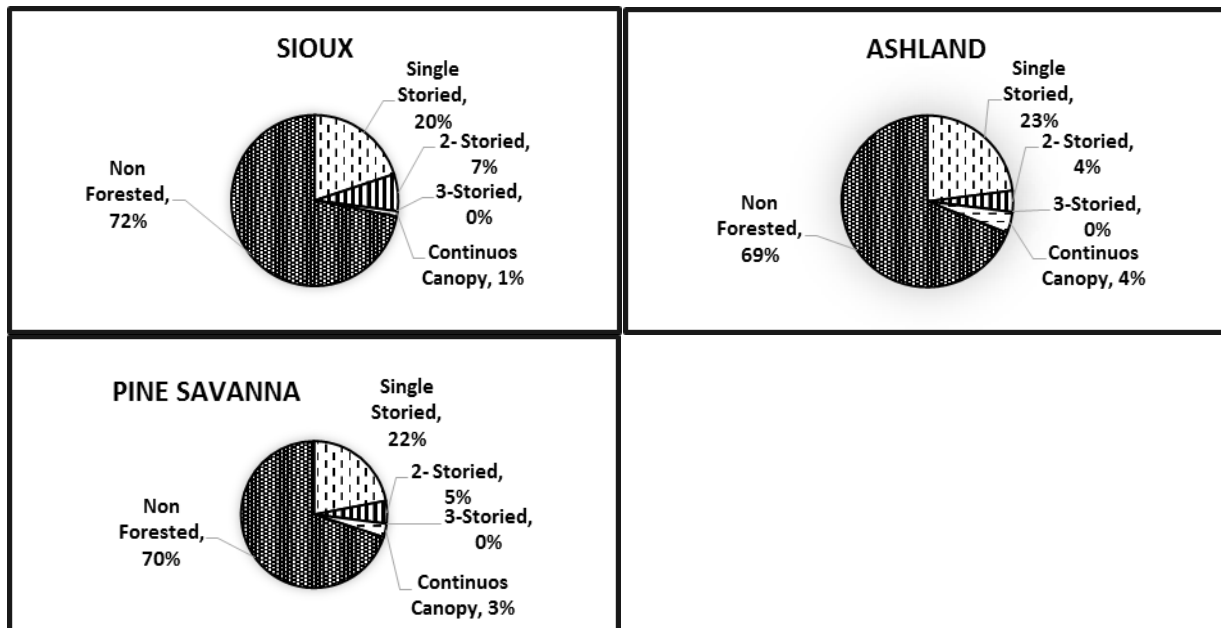
## Forested Vertical Structure

Proportions of vertical structure of the forested vegetation is one of the key ecosystem characteristic indicators to assist in describing structure. Vertical structure depicts the number of vertical canopy layers of tree lifeform present. In general these layers may correspond to tree ages, but not necessarily. The Region 1 classification identifies 4 vertical structure classes and assigns live basal area to the diameter classes based on the inventory data to determine these vertical structure classes (Barber et al. 2011). Following is the description of these classes and proportion of structure classes across the analysis areas.

**Table 8. Vertical structure class descriptions**

Vertical Class	Structure Description
1	Single-storied, dominated by a single canopy layer. Generally corresponds to even-aged stands which is typical of some cover types such as lodgepole pine.
2	Two-storied, with a dominant overstory and an understory which usually corresponds to a second age class but may also represent a suppressed layer the same age as the canopy.
3	Three-storied, with three distinct layers present, which often correspond to a dominant overstory and two younger age classes but may also represent suppressed layers of the same age as the dominant canopy
C	Continuous canopy layering. This usually corresponds to shade tolerant cover types such as spruce/fir and/or forests at or near climax where shade tolerant layers have established. Can also correspond to shade intolerant cover types such as dry ponderosa types with suppressed understory of ponderosa pine.





**Figure 23. Proportion of forested vertical structure classes on the analysis areas and ecological unit, R1 summary database, forest inventory and analysis plots**

The forest inventory and analysis data indicates the montane unit has the most area classified with an existing forested structure (68 percent). Single storied structure is the most dominant vertical structure across the forest. The montane unit has cover types that without disturbance the successional pathway allows for tolerant species to develop and grow underneath the canopies, thus creating layers. In addition they have a cover type of lodgepole pine that tends to dominate as single story until later in their successional pathway. The pine savanna unit has only 7 percent of the forested area with 2 or more canopy structures. These units without disturbance may develop with more than one canopy layer. Frequent low fire severity would maintain the majority in single to two storied structure. The extensive fires over the last 15 years likely reduced areas of multiple canopies, without additional fire these may develop into a patchy/clumpy multi canopy condition.

#### *Madison, Henrys Lake, Gallatin, Absaroka, and Beartooth Mountains*

Of the approximately 68 percent of forested area, single story canopy layers dominates the area at 42 percent. The area has 15 percent represented with a continuous canopy layer and 11 percent with a 2-storied canopy structure. Three storied canopy structure is rare and estimated on 0.4 percent of the area.

#### *Bridger, Bangtail, and Crazy Mountains*

Single storied structure dominates the forested area (55 percent). Continuous canopy layer representation is very similar to the Madison, Henrys Lake, Gallatin, Absaroka and Beartooth Mountains at 16 percent of the area. Two storied structure is estimated on 8 percent and 3-storied did not occur on the inventory plots.

#### *Pryor Mountains*

Of the approximately 49 percent forested area, single storied structure dominates 43 percent of the landscape area. Continuous canopy, 2-storied, and 3-storied are less common on the landscape and each are represented on 2 percent of the area.

### *Ashland District*

The forested landscape area (31 percent) is dominated by a single-story structure (23 percent). Three-story structure was not represented on the inventory plots and 2-storied and continuous canopy structures both are represented on 4 percent of the area.

### *Sioux District*

Like the Ashland District the forested landscape is dominated by single-story structure (20 percent). Three-storied structure was not represented. Two-storied was estimated on 7 percent and continuous canopy structure on 4 percent of the area.

### *Trends*

Like with other attributes of structure, vertical structure class is driven by succession, individual species growing traits, and disturbances that take place. In general, mid-successional forests are often associated with higher tree densities and an increase in canopy layers in some of the forest types found on the Custer Gallatin National Forest. Dependent on cover type, this structure can vary temporally and spatially. Examples of this include:

- Ponderosa pine cover types tend to have reduced canopy layers and/or a clumpy or uneven aged character with frequent natural fire disturbances that limited understory development. Another structure characteristic with repeated fires in these dry type forests could be a continual reduction of canopy promoting establishment of multiple canopy layers in various patch size and densities depending on severity of the fire. With fire exclusion on the montane unit where ponderosa pine is associated with other species such as Douglas-fir continuous canopy layers may be more prevalent as frequent fires would have limited more tolerant understories from developing.
- Ponderosa pine on the pine savanna unit with fire exclusion trend to higher and more continuous canopy cover patches with understories that have attempted to develop with limited resources. This results in areas crisscrossed with live and dead understory trees that are more susceptible to insect, snow, and wind damage. This type of fuel complex is likely not common under a natural high frequency, low intensity fire regime and increases risk of stand replacement wildfire. This structure was much more common across the landscapes prior to the large fires over the last 15 years, which was likely promoted the intensity and spread of these fires. Current vertical structure on the remaining forested area at the broad scale maybe more in line with what might have occurred with repeated fires.
- In some Douglas-fir stands natural fire disturbances would create small canopy breaks promoting establishment of trees and thus a new canopy layer. In the absence of fire or other disturbances, a closed single story structure may persist, or where more tolerant associated species are present multiple canopy layers could develop. In some areas of the Custer Gallatin National Forest, where Douglas-fir is associated with other conifer species, multiple canopy layers may be more prevalent than they were historically when periodic fires kept understories from establishing.
- Lodgepole pine cover types tend to establish post disturbance and grow in a single storied structure in early to mid-succession. In the absence of stand replacing disturbance (fire or insects), tolerant conifer species may slowly establish in the understories creating multiple canopy layers.

- Spruce/subalpine fir cover types, which are dominated by shade tolerant species tend to develop into multiple canopy layer structure.

Future trends in vertical structure will be influenced by the same processes and ecosystem drivers that are discussed in other sections. Ecosystems and the interrelated processes associated with them are complex. Understanding these while considering uncertainties of climate change to predict future conditions also comes with uncertainties. Predicted warmer, drier climate will likely increase the extent and severity of disturbance events such stand replacement wildfire and insect activity. This will likely change the extent and arrangement of vertical structure across the landscape. See Forest Vegetation Drivers and Trends section for further discussion.

## Forested Canopy Density Class

Tree canopy cover is used to depict the density of existing forested vegetation. Canopy cover refers to the proportion of the forest floor covered by the vertical projection of the tree crowns, as viewed from the air. The measure used to describe this key ecosystem characteristic is the percent of area represented in canopy cover classes. The Region 1 classification uses four canopy cover classes (tree density) and two non-forest classes as indicated in Table 9 below.

**Table 9. Forested canopy density (canopy cover) class descriptions**

<b>Canopy Cover Class</b>	<b>Description</b>
Non-forested	Less than 10 percent tree canopy cover. Corresponds to grass or shrub dominance types. This includes potential forested sites that are still in transitions from large disturbances (that is, forest cover has not reestablished).
Sparse	Less than 10 percent tree canopy cover not considered a grass/shrubland – such as rock scree.
Low Tree Cover	10 to 25 percent canopy cover. These tend to be open, dry forest types in transition areas with grass/shrublands; in more productive forests that have been recently disturbed; or seedling/ sapling forests where the regeneration has not yet closed.
Moderate Tree Cover	26 to 40 percent canopy cover. This class tends to represent open growing cover types and/or early to mid-seral forests where canopies have not completely closed.
Mod/High Tree Cover	41 to 60 percent canopy cover. This class tends to represent more closed canopy cover types and mid to late seral forests where canopies have begun to close.
High Tree Cover	Greater than 60 percent canopy cover. These are very dense forests and tend to be either seedling/saplings, cover types that tend to grow at high density such as spruce/fir, and/or mid to late successional forests where canopies have closed.

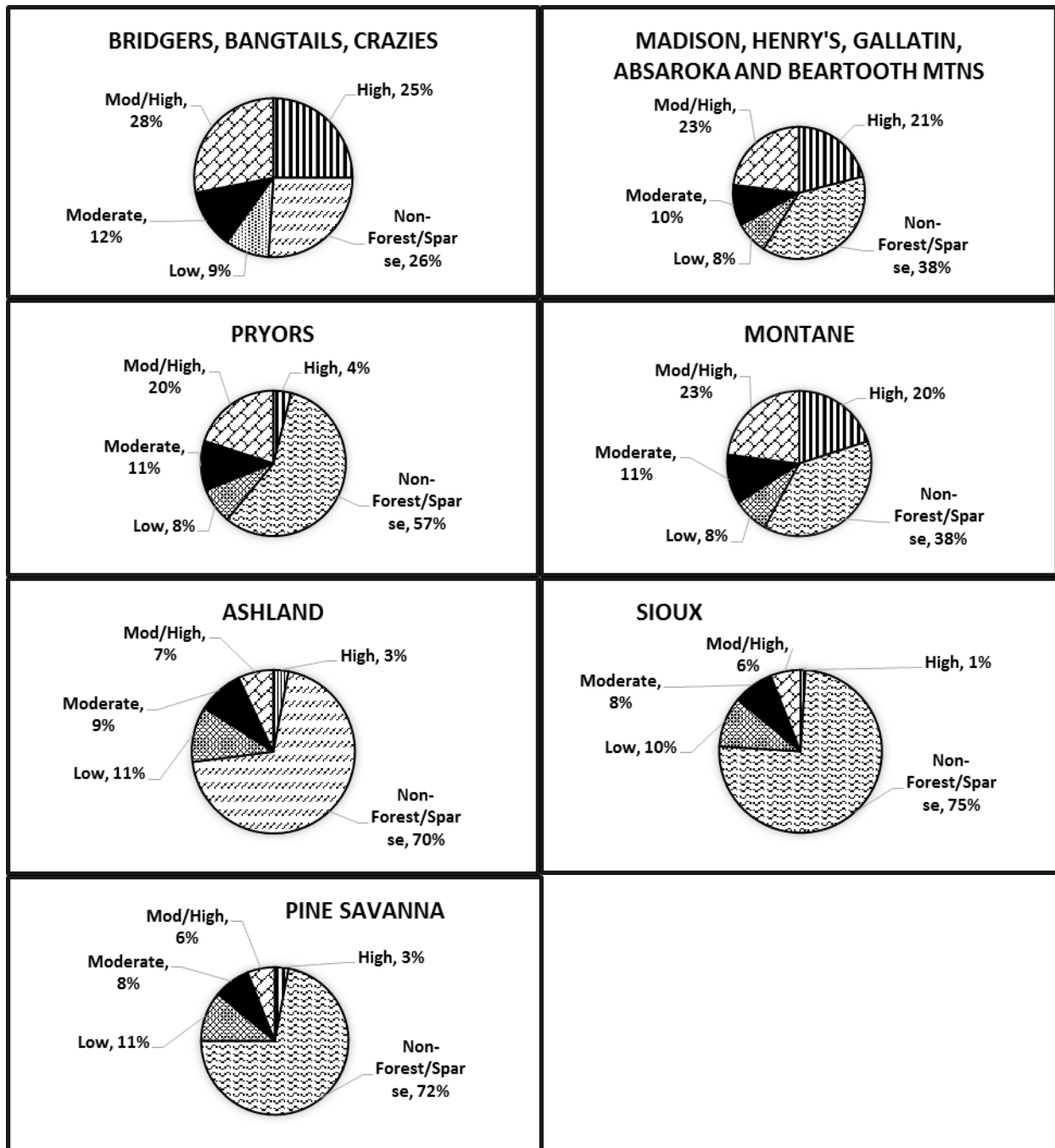


Figure 24. Proportion of forested canopy density classes by analysis area and ecological unit, R1 summary database, forest inventory and analysis plots

The forest inventory and analysis data shows that the higher canopy cover classes (moderate/high and high; 41 to greater than 60 percent) dominate on the montane unit and the lower canopy classes (moderate and low; 10 to 40 percent) dominate on the pine savanna unit. The lower canopy densities of ponderosa pine on the pine savanna unit is due to the character of the clumpy growing nature. Within these clumps canopy densities are high, at the broader sampling scale this condition tends to get averaged in. Both the montane and the pine savanna units likely have an existing higher non-forested/sparse class than what the potential for forest cover (greater than 10 percent canopy cover)

may be. Large fires especially on the pine savanna unit likely have moved a large percent of previous forest cover into a tree canopy cover less than 10 percent. On both ecosystems, past wildfire has potentially changed canopy class distributions from higher canopy cover classes (greater than 41 percent) lower canopy cover classes (10 to 40 percent) from mixed severity fire activity. Below is a description of canopy density class by analysis areas.

#### *Madison, Henrys Lake, Gallatin, Absaroka, and Beartooth Mountains*

Forty-four percent of this analysis area has a canopy cover greater than or equal to 40 percent. Twenty-one percent has a canopy cover greater than or equal to 60 percent. Eighteen percent has a canopy between 10 and 40 percent. Potential for forested vegetation on this land unit is estimated at 85 percent of the area (Table 6). Currently forested canopy cover (greater than or equal to 10 percent) occurs on about 62 percent of the analysis area.

#### *Bridger, Bangtail, and Crazy Mountains*

The highest amount of area in canopy cover greater than or equal to 40 percent occurs in this land unit at 53 percent. Canopy cover between 10 and 40 percent is estimated at about 21 percent of the area. This unit has the smallest difference between estimated potential forest vegetation compared to existing forested canopy cover greater than or equal to 10 percent. Potential forest vegetation types is at 88 percent (Table 6) and existing forested canopy cover (greater than or equal to 10 percent) is at 74 percent.

#### *Pryor Mountains*

Nineteen percent of the area has a canopy cover between 10 and 40 percent. Canopy cover greater than 40 percent is estimated to occur on 24 percent of the area. Existing forested canopy cover (greater than or equal to 10 percent) is estimated at 30 percent while potential forest vegetation is estimated at 71 percent (Table 6).

#### *Ashland District*

Moderate and low canopy cover is estimated at 20 percent of the area. Ten percent of the area has a canopy cover greater than 40 percent, with 3 percent greater than 60 percent. Past fire disturbance is likely the result of existing canopy cover greater than or equal to 10 percent estimated at 30 percent of the area and the potential forested vegetation at 75 percent (Table 6). This area has the largest difference between these two attributes.

#### *Sioux District*

This land unit has the least amount of estimated high canopy cover (greater than 60 percent) of all land areas at 1 percent. Canopy cover between 10 and 40 percent dominates at 18 percent, while canopy cover greater than 40 percent is estimated at 7 percent of the area. Forty-seven percent of the area has potential for forested vegetation. Existing forested canopy cover greater than or equal to 10 percent is estimated on 39 percent (Table 6).

#### *Trends*

Natural succession, species growing traits, and disturbance processes drive how density classes (canopy cover) will persist on the landscape or exist at various points in time. Generally as trees establish post disturbance, and grow; tree crowns expand increasing density (canopy cover) over time; and as individual trees or groups of trees continue to grow mortality may occur. Mortality can result from competition for light, water, and nutrients, to low fire severity, to endemic insect activity, to high fire



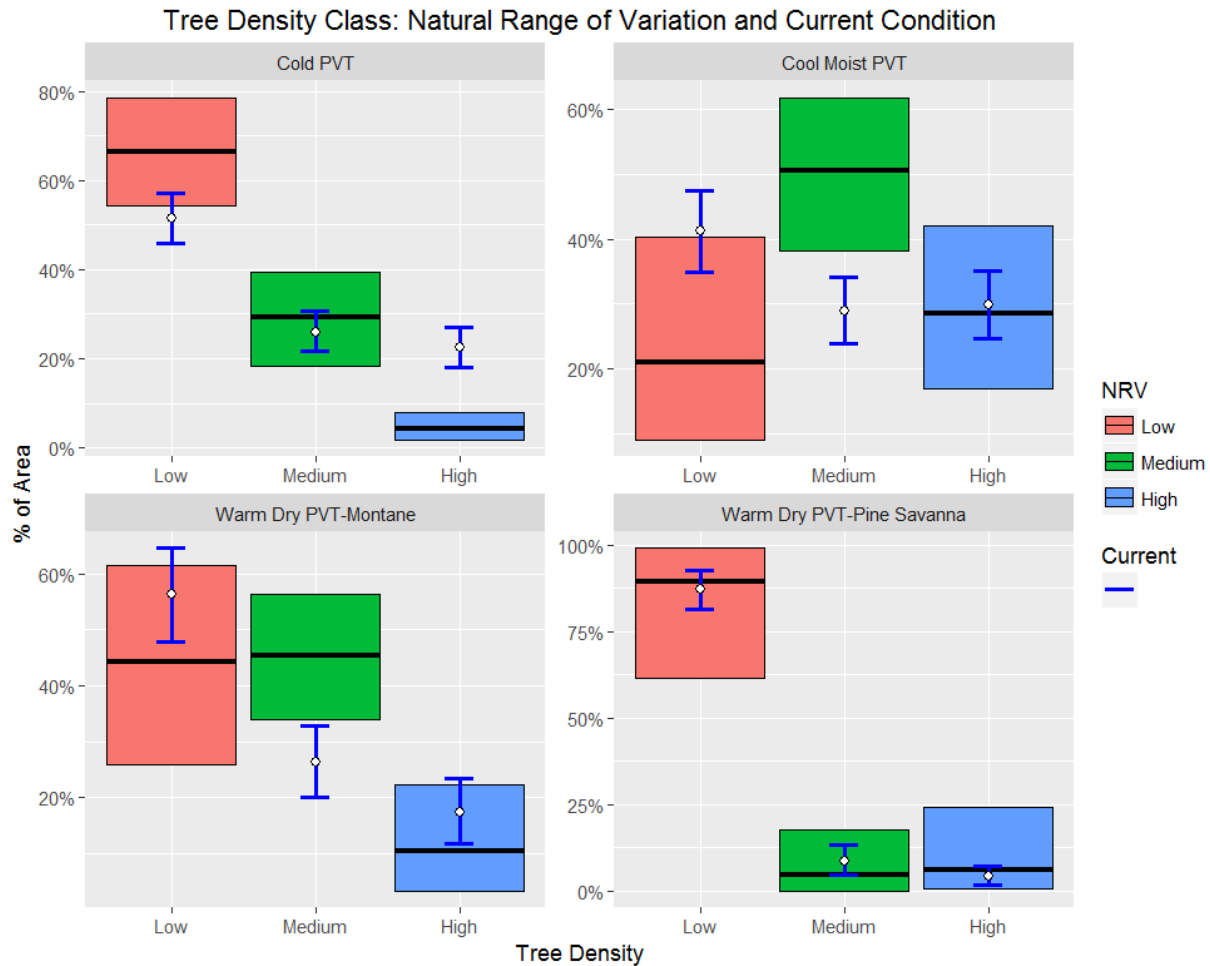
severity, to epidemic insect outbreaks. These can all reduce density by individual trees or groups of trees all having various levels of density reduction.

In addition, growing traits of individual species may result in density differences. Ponderosa pine on dry sites tends to generally grow in small clumps and more open conditions with natural disturbance regimes. However, species like lodgepole that generally develop very dense post disturbance tend to stay dense without disturbances. Dry cover types can result in higher canopy densities with fire exclusion. High densities in forests tend to predispose them to stand mortality from fire and insects.

Human activities, insects, and climate change will likely influence future trends in density classes. Successional processes under warmer, dryer climates may be altered in complex and uncertain ways (see “Forest Vegetation Drivers and Trend” section below). Warm conditions may increase the extent and severity of disturbances which increase the amount of non-forested areas, or they could thin some forests and reduce densities. Successional processes may also be altered by human activities such as fire suppression, favoring development of denser forests. However, this pathway could be interrupted by vegetation management and/or fire that could reduce the development of dense forests. Drier periods may not have enough moisture to support tree establishment post disturbance or growth. Human activities and climate change will influence the temporal and spatial distribution of forest density and be further determined with the interactions of ecosystem drivers such as wildfire and insects.

#### **Tree Density Class – Natural Range of Variation**

The SIMPPLLE landscape dynamics simulation model was used to estimate the Natural Range of Variation of tree density classes across the Custer Gallatin National Forest. Comparing the Natural Range of Variation to the current condition provides important information regarding the ecological integrity of this key ecosystem characteristic. Figure 25 displays the results of the Natural Range of Variation analysis for tree size class. Results have been grouped by the Region 1 Broad Potential Vegetation Types (PVTs; Milburn et. al 2015).



**Figure 25. The Natural Range of Variability (NRV) for tree density class within the three forested Region 1 Broad Potential Vegetation Type groups found on the Custer Gallatin National Forest (see Milburn et. al 2015 for a description of the Potential Vegetation Types). Tree density is measured as canopy cover and divided in to three cover classes: 0-40% (Low); 40-60% (Medium); and >60% (High). The Warm Dry Potential Vegetation Type has been split between the Pine Savanna and Montane ecosystems. The mean (horizontal black bars) and 90 percentile range (colored blocks) of the simulated Natural Range of Variation are shown. Forest Inventory and Analysis (FIA) data was used to estimate the mean (white dots) and 95% confidence interval (blue bars) of the current conditions.**

In the Cold Potential Vegetation Type, there is an excess of high density areas (>60% canopy cover) but a deficit of low density (<40% canopy cover) relative to the Natural Range of Variation. This is likely due to the fire suppression allowing for the establishment and persistence of shade tolerant species like Engelmann spruce and subalpine fir at the expense of more open stands of white bark pine. The SIMPPLLE model results also suggest that the Warm Dry Potential Vegetation Type was historically characterized by open stands with relatively little high density areas. In the Pine Savanna ecosystem, recent large and severe fires significantly reduced the amount of high and medium density stands while increasing the amount of low density area in the Potential Vegetation Type. However, due to the high severity of these recent fire events, the spatial distribution of low-density areas across this Potential Vegetation Type is likely concentrated in the areas with recent fire. SIMPPLLE model results further suggest that the late-seral, open canopy component of this Potential Vegetation Type is particularly diminished relative to the natural range of variation.

## Dead Trees, Snags by Size Class

### *Existing Condition*

Dead trees (snags) have been identified as a key structure characteristic that provides important habitat. Snags can be created at multiple temporal and spatial scales. They can be created from processes where trees die slowly from decay or environmental impacts (lightning, wind breakage, snow load breakage) or they can be created more quickly from individual tree mortality to multiple tree/large stand mortality from disturbance events such as fire or insect activity.

All snags have value, but of particular importance are larger snags due to their less common presence or rarity on the landscape and their high habitat value. The forest inventory and analysis inventory plots were used to assess three general size classes of dead trees: medium (10 to 14.9 inches in diameter at breast height); large (15 to 19.9 inches in diameter at breast height); and very large (greater than or equal to 20 inches in diameter at breast height).

Estimates of mean (estimate) snag density are from forest inventory and analysis data and displayed below with their respective 90 percent confidence intervals (low to high), which provide an indication of the reliability of the estimate. At a confidence level of 90 percent, unless a 1 in 10 chance has occurred, the true population mean is within this interval.

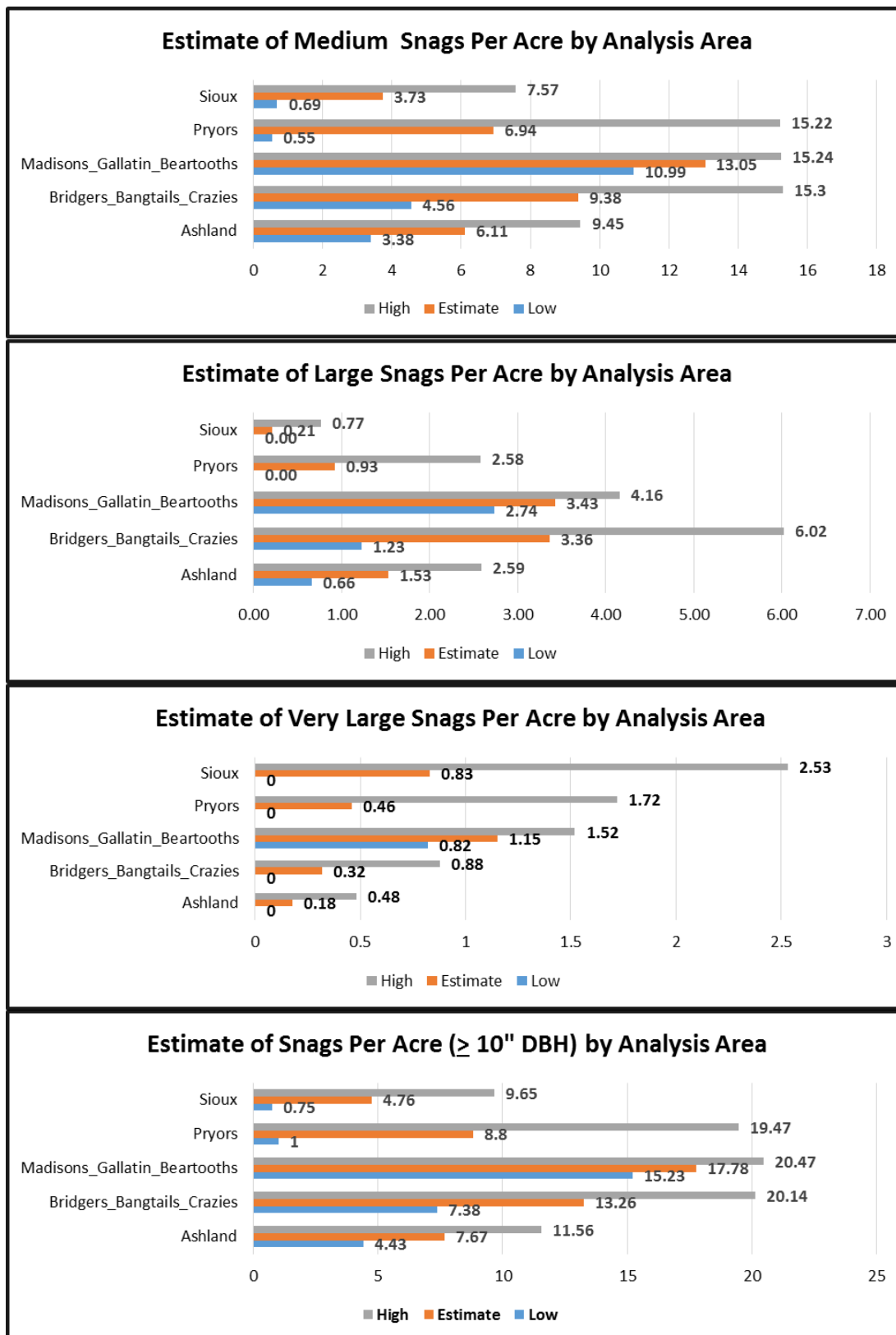


Figure 26. Estimate of snags per acres by size groups by analysis area, R1 summary database, forest inventory and analysis plots

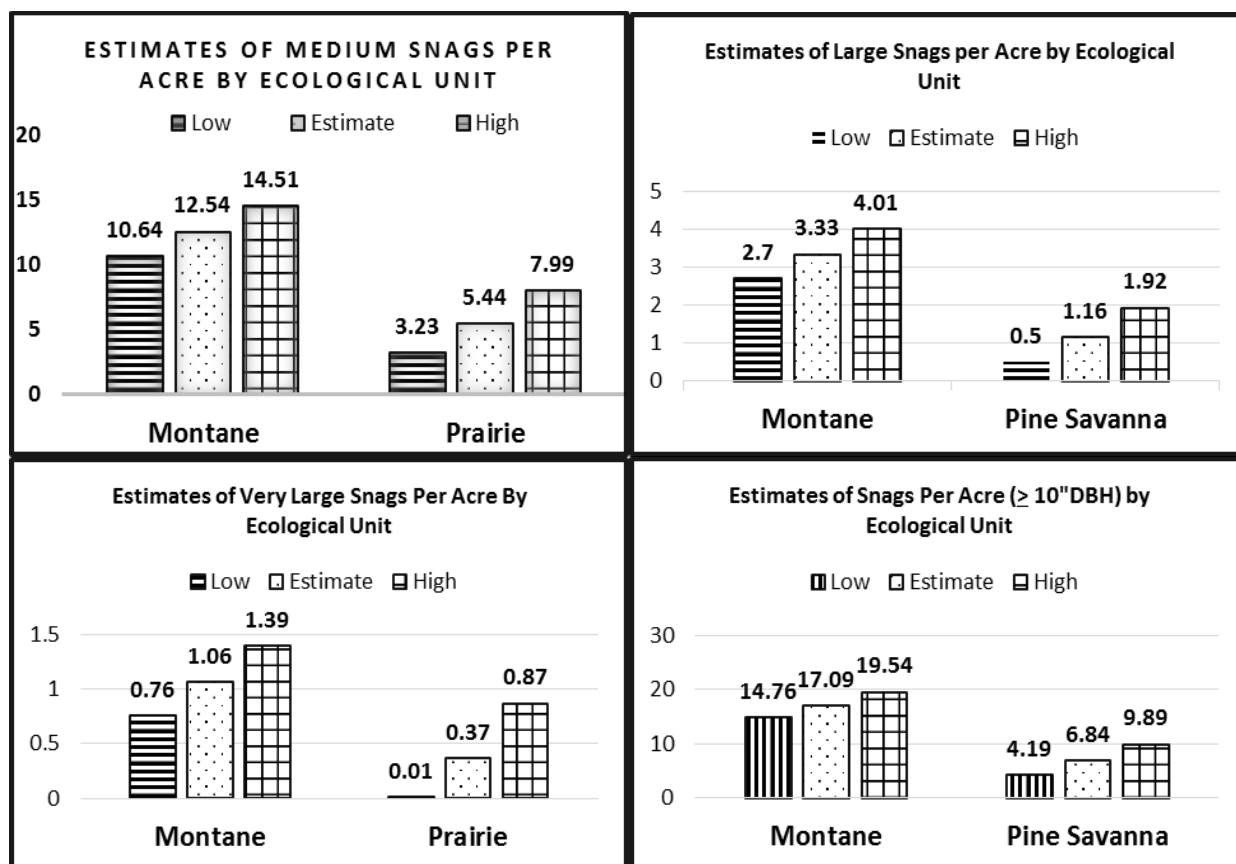


Figure 27. Estimate of snags per acre by size groups by ecosystem unit, R1 summary database, forest inventory and analysis plots

**Table 10. Dead trees (snags) per acre by size class by ecological unit and analysis area, R1 summary database, forest inventory and analysis plots**

	Ecological Unit		Analysis Area				
	Montane	Pine Savanna	Ashland	Bridgers, Bangtails, Crazies	Madison, Henrys, Gallatin, Absaroka and Beartooth Mtns	Pryors	Sioux
Species	Medium Size Snags/Acre						
Subalpine fir	2.43			2.59	2.37	3.7	
Juniper		0.59	0.82				
Whitebark pine	3.31			2.14	3.55		
Lodgepole pine	4.97			3.11	5.23	2.78	
Engelmann spruce	0.92				1.04		
Limber pine	0.35			1.16	0.27	0.46	
Ponderosa pine	0.03	4.85	5.29		0.04		3.73
Aspen	0.02				0.02		
Douglas-fir	1.11			0.39	1.22		
	Large Size Snags/Acre						
Subalpine fir	.4			0.84	0.35	0.46	
Juniper		0.12	0.16				
Whitebark pine	1			0.78	1.06		
Lodgepole pine	1.05			0.97	1.1		
Engelmann spruce	0.58			0.39	0.61	0.46	
Ponderosa pine		1.04	1.37				0.21
Aspen							
Douglas-fir	0.45			0.78	0.42	0.46	
	Very Large Size Snags/Acre						
Subalpine fir	0.04				0.05		
Whitebark pine	0.22				0.25		
Lodgepole pine	0.07				0.08		
Engelmann spruce	0.45				0.5	0.46	
Limber pine	0.05			0.19	0.04		
Ponderosa pine		0.37	0.18				0.83
Douglas-fir	0.23			0.13	0.25		

The montane unit has the highest estimated dead trees per acre greater than or equal to 10 inches in diameter at about 17. Medium sized snags are estimated at 12.54, large snags at 3.33, and very large snags at 1.06 per acre. The shade intolerant species more common in the medium and large size classes are lodgepole pine, whitebark pine, and Douglas-fir and make up about 71 percent of these classes. Lodgepole pine is one of the more common tree species on the montane units of the Custer Gallatin National Forest and typically characterized by their growth, form, and lack of wind firmness (Alexander 1986, Schmidt and Barger 1986). Lodgepole pine is a shorter lived species and fails to grow as large as other common tree species on the Custer Gallatin National Forest, and generally does not contribute as

many very large diameter snags. Whitebark pine is a longer-lived species and tends to grow to larger sizes. Recent fires in the lodgepole pine cover types and mountain pine beetle mortality in the both lodgepole pine and whitebark pine is likely a factor in the existing representation of snags. Limber pine and ponderosa pine snags are rare. Shade tolerant species subalpine fir and Engelmann spruce are more common in the medium size and less common in the large and very large size classes. Engelmann spruce, Douglas-fir, and whitebark pine make up 85 percent of the very large size class; lodgepole pine, limber pine, and subalpine fir are less common.

The pine savanna unit has an estimate of about 7 snags per acre greater than or equal to 10 inches in diameter. Ponderosa pine snags are most represented in the medium and large size classes and rare in the very large. One would expect with recent fires on the pine savanna unit, ponderosa pine snags should be more plentiful. However, bases of these trees were not exposed to multiple fires that would have hardened them with resin allowing them to be more wind firm. These landscapes are frequented by high winds and 90 to 95 percent of these fire killed trees are down within 6 to 10 years. Although rare, juniper snags are present in the medium and large size classes.

Not surprising hardwood snags greater than or equal to 10 inches in diameter are very rare, as indicated by 0.02 snags per acre presence of aspen in the medium size class on the montane unit. The inventory did not sample any hardwood snags greater than or equal to 10 inches in diameter on the pine savanna unit.

#### *Madison, Henrys Lake, Gallatin, Absaroka, and Beartooth Mountains*

This land area has the highest estimated snags per acre greater than 10 inches at 17.63. Medium size snags dominate this total at 74 percent, followed by 19 percent large size and then 7 percent very large. This land area has the greatest diversity of species of snags. Eight species are represented (subalpine fir, whitebark pine, lodgepole pine, Engelmann spruce, limber pine, ponderosa pine, aspen, and Douglas-fir).

Lodgepole and whitebark pine are most common in the medium class (38 percent and 26 percent). Subalpine fir, Douglas-fir, and Engelmann spruce are less common (17 percent, 9 percent, and 7 percent). Limber pine, ponderosa pine, and aspen are rare representing less than 1 percent of the snags. Lodgepole pine and whitebark pine dominate the large size (31 percent and 30 percent). Engelmann spruce, Douglas-fir, and subalpine fir are less common (17 percent, 12 percent, and 10 percent).

Although rare at 1.15 snags per acre, six species are represented in the very large size class. Engelmann spruce is most common (43 percent), followed by whitebark pine and Douglas-fir both at 21 percent of the total. Lodgepole pine, subalpine fir, and limber pine each represent less than 10 percent of the total (7 percent, 4 percent, and 3 percent).

#### *Bridger, Bangtail, and Crazy Mountains*

There are about 13 snags per acre greater than 10 inches in diameter. Medium snags make up about 72 percent, large snags 26 percent, and very large snags 2 percent. This area has the second highest medium and large snags per acre. Lodgepole pine is the most common species in the medium and large size, but is absent in the very large class. Whitebark pine, subalpine fir, and limber pine are the next most common in the medium class at 63 percent of the snags. Douglas-fir in the medium class represents 4 percent. Lodgepole pine is the dominant snag in the large size class (26 percent), while subalpine fir, white bark pine, and Douglas-fir each represent about 21 percent of this class. Engelmann spruce makes up about 10 percent.

Limber pine and Douglas-fir are the two species that make up the very large class. Limber pine represents 59 percent of this class. Snag dominance by whitebark pine and limber pine is likely due to recent fires and mountain pine beetle mortality.

### *Pryor Mountains*

Snags per acre greater than 10 inches are estimated at 8.33 per acre. The medium size class represents 83 percent, large size class 11 percent, and very large size class 6 percent of the total. Subalpine fir is the most common species in the medium size class (83 percent), followed by lodgepole pine (11 percent), and limber pine (6 percent). The large size class is equally represented by subalpine fir, Engelmann spruce, and Douglas-fir. Engelmann spruce makes up the very large class at less than 1 snag per acre.

### *Ashland District*

Total snags per acre greater than 10 inches in diameter are estimated at 7.82. Medium snags represent 78 percent, large 20 percent, and very large 2 percent of the total. Ponderosa pine makes up 87 percent of the medium class, 89 percent of the large class, and 100 percent of the very large class. The only other species sampled was juniper; it makes up the balances.

### *Sioux District*

This land unit has the smallest estimated snags per acre greater than or equal to 10 inches in diameter at 4.77. Like all the other lands areas, the medium class represents the largest portion of the total (78 percent). The very large size makes up about 17 percent and the large class 4 percent of the total.

In 2008, estimates of snags for the east side forests in Region 1 was compiled based on forest inventory and analysis plots available (Bollenbacher et al. 2008). They found in general there were fewer snags outside of wilderness and roadless areas (Table 11 below). They noted that the larger the snag, the less common it is largely due to: less trees living to an older age; as trees age, they grow slower and less likely reach very-large diameters; and various types of disturbance agents that kill and remove them results in few large old trees and snags.

**Table 11. Mean snag densities per acre with 90 percent confidence interval (CI), by diameter classes, inside and outside of wilderness/roadless areas**

Area		Snags per Acre 10" +			Snags per Acre 15" +			Snags per Acre 20" +		
		Mean	90% CI-Lower Bound	90% CI-Upper Bound	Mean	90% CI-Lower Bound	90% CI-Upper Bound	Mean	90% CI-Lower Bound	90% CI-Upper Bound
In Wilderness or Roadless	Custer	12.7	7	19.4	3.8	1.8	6.2	1	0.4	1
	Gallatin	17.6	14.4	21.1	4.7	3.7	5.9	1.3	0.9	1
Outside Wilderness or Roadless	Custer	3.2	1.5	5.2	1.1	0.4	1.8	0	0	0
	Gallatin	7.4	4.2	11	2.5	1.2	3.9	0.4	0.1	0

Exploring the density of snags in wilderness and roadless areas can provide insight to natural snag abundance and distribution on a Forest. These can be compared to paired field plots outside wilderness and roadless areas to help to understand differences between areas that have been influenced by management and unmanaged areas. There is some uncertainty how climate, a period of cool and moderate precipitation, and fire suppression from 1930 to 1985 has affected snag density and



distribution in wilderness and roadless areas. Harris (1999) notes similar uncertainty concerning effects of fire suppression on creation of snags in unharvested areas of western Montana. However, even with some degree of uncertainty it is the best quantitative data available to represent unmanaged forested systems. As such, the data presented in the table above and in Bollenbacher and others (2008) for snags in wilderness and roadless areas represents the natural range of variation for this key ecosystem characteristic.

Bollenbacher and others (2008) also analyzed habitat groups (warm, cool, and cold) that have similar disturbance regimes within the groups and some general insight to how snags are produced. Characteristic disturbances contribute to snag abundance, during various stages of succession, in different ways and produce different numbers of snags. Frequent, low- to mid-severity fire in the warm habitat group tend to produce a relatively constant level of snags at low numbers. The cool group, with a characteristic fire regime that tended to have less frequent, but with more severe fires, produced pulses of snags, and generally a greater quantity of snags, especially early in the forest succession cycle. Then as stands aged, the density of snags increased, until another high- severity stand replacing fire occurs. The cold types tend to produce high snag densities as characteristic disturbance regimes produced persistent snags over a long periods due to colder climates, where decomposition rates are slower, and the period of time between stand replacing events were likely the longest.

Bollenbacher and others (2008) showed that large snags are rare in all types, but tend to occur in cool habitat type groups and are likely to be Douglas- fir or Engelmann spruce. Snags in lodgepole pine types are mostly distributed in the smaller size class. In cool habitat types and lodgepole pine, early seral stands have the most snags due to stand-replacing fires. Warm types have a more even distribution of snags into later seral stages because of a more frequent, less severe fire regime. All groups show fewer mid-seral stage snags as snags transition to downed wood.

Bollenbacher and others (2008) also showed that snags are generally distributed in clumps across the landscape. This, in part, is because many snags are the result of periodic, broad-level disturbances, fire and insects, which create large areas which have more snags than outside of those disturbed areas (Bollenbacher et al. 2008, Harris 1999).

### *Trend*

Presence of snags and creation of snags on the landscape is dynamic and influenced by natural processes (fire, insects, and succession), human actions, and climate change. How these disturbances interact on the landscape can influence snag numbers and presence. Pulses of snags created by large scale disturbances (fire and insects) or limited snags created by small scale disturbances (individual or small groups of mortality) can be reduced by human actions (salvage and/or firewood cutting) in some areas. Management actions that increase stand resilience to large disturbance could reduce the creation of snags at small scales.

Currently snags in the medium size class, especially lodgepole pine and whitebark pine are the most abundant. This abundance in the short term, created by recent fires and mountain pine beetle will be lost over the long term as these snags fall. The timing of when dead trees fall varies by species, the cause of mortality, and site conditions. Studies suggest that the range of when most trees fall is usually between 3 and 15 years after death (DeNitto et al. 2000, Mitchell and Preisler 1998, and Lyon 1977).

Natural processes and disturbance events such as insects, diseases, wildfires, lightening, wind, and heavy wet snow events will continue to create snags temporally and spatially. Changing climate may further stress trees and alter stand conditions to make them more susceptible to these agents (see

Forest Vegetation and Trends section). Fire exclusion tends to create homogeneous landscapes that have a structure more susceptible to wildfire (Keene et al. 2002). Large disturbance events in these homogeneous landscapes and predicted future climate conditions that may promote large disturbance events, will create pulses of snags followed by a period of few snags as is seen currently in the older wildfire areas on the pine savanna unit. These pulse events will result in snags not being well distributed spatially or temporally.

Large snags are a function of development of large trees. As previously discussed large trees are not common on the Custer Gallatin National Forest due to several factors. For example, much of the forested land on the Custer Gallatin is moisture limited. In these areas, current high stand densities resulting from fire suppression has led to high competition for available moisture. These two factors along with others discussed previously limit tree growth and hence the development of large trees and snags.

### *Information Needs*

The Bollenbacher et al. (2008) analysis of snags densities in managed and unmanaged area will be redone to analyze the Custer Gallatin National Forest as a single administrative unit. The results of this analysis will help form the basis for determining the natural range of variation for snags as well as enable the forest to monitor snags over time at the broad-level and adaptively manage project-level considerations, as snag densities change over time.

## **Large Woody Debris - Quantity of Large Down Wood Greater Than or Equal to 3 Inches in Diameter**

### *Existing Condition*

Large woody debris was determined to be a key characteristic for assessing the structure of the forested systems due to its importance to fire behavior, site productivity, nutrient cycling, and wildlife habitat value (Graham et al. 1994). Forest inventory and analysis plots were used for this analysis to see how many tons per acre of large woody debris currently exists across the Custer Gallatin National Forest.

Large woody debris for this analysis is wood that is at least three inches in diameter and lying on the ground. Important attributes of large woody debris include:

- Decomposition is generally slower on dry sites than on moist sites.
- Quantity of downed large wood is influenced by fire regimes.
- High severity regimes result in pulses of downed wood by allowing material to build up between infrequent fires and then consuming most of it in a single fire event.
- High frequency, low severity fires support a more consistent, low level of debris which is continually consumed and recruited by repeated fire events.

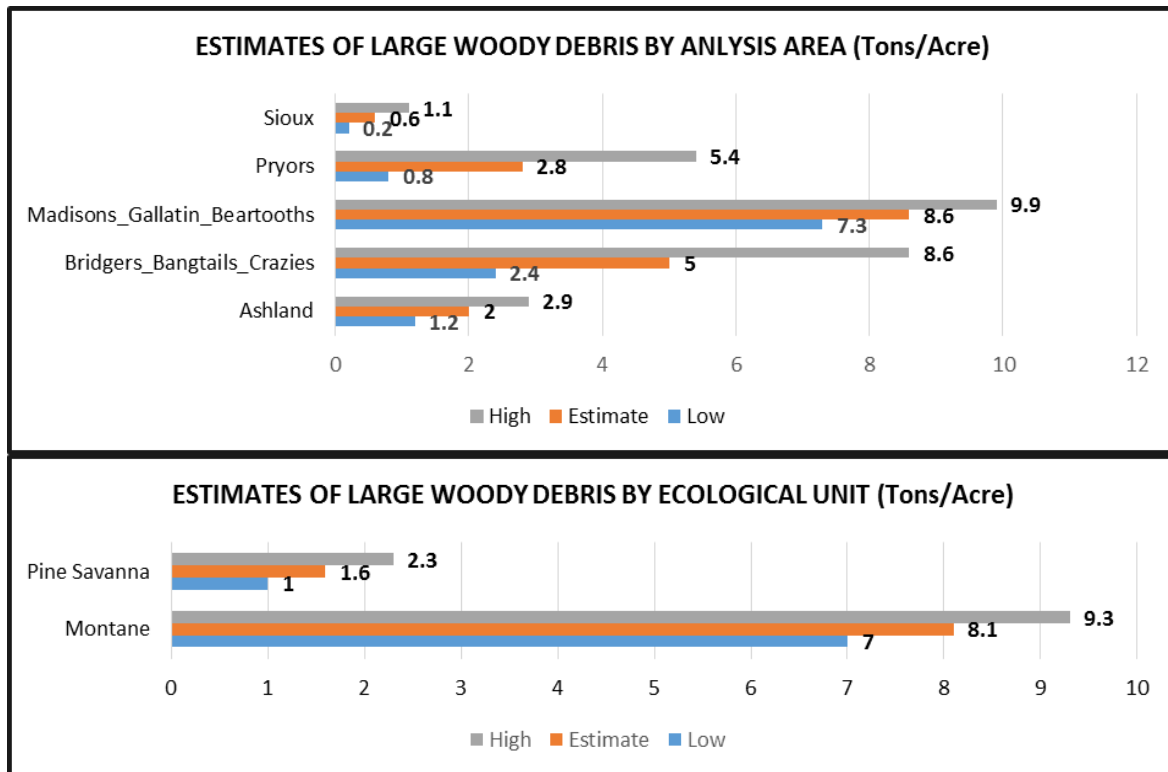


Figure 28. Estimates of large woody debris (tons/acre) by analysis area and ecological unit, R1 summary database, forest inventory and analysis plots

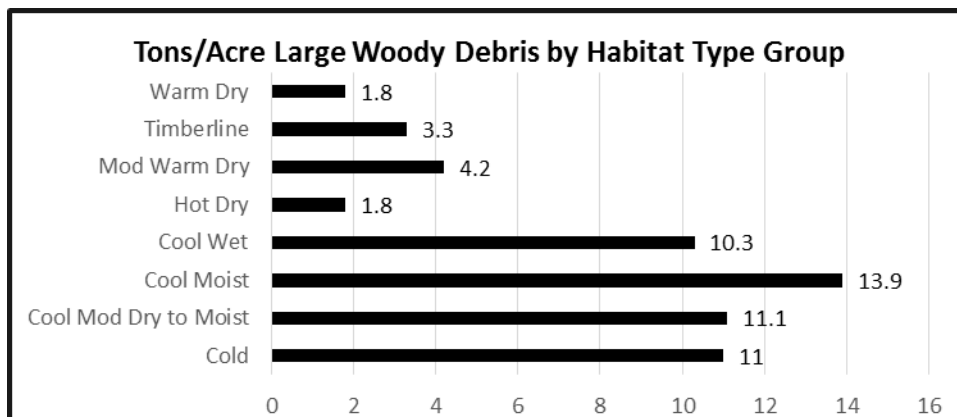


Figure 29. Tons per acre of large woody debris greater than or equal to 3 inches in diameter, Custer Gallatin National Forest - R1 summary database, forest inventory and analysis plots

The montane unit has a dominance of moist habitats with more high severity low frequency fire regimes. Conversely the pine savanna unit has a dominance of dry habitats and low severity high frequency fire regimes. Not surprising the montane unit have higher tons per acre of large woody debris than the pine savanna unit (estimate of 8.1 versus 1.6). Except for the timberline habitat type group the trend for lower tons per acre on the dry habitat types holds. Hot dry, warm dry, and moderately warm dry all have lower estimated tons per acre than do the moist, cool and wetter habitat type groups (Figure 29Error! Reference source not found. above). The timberline habitat group has both a mixed severity and fire frequency fire regimes, which may explain the lower tons per acre.

*Madison, Henrys Lake, Gallatin, Absaroka, and Beartooth Mountains*

This land area is the largest and has more dominance of moist, cool, cold, and wet habitat types with an estimated 8.6 tons per acre of large woody debris, with a range of 7.3 to 9.9. These habitat type groups make up about 61 percent of the area.

*Bridger, Bangtail, and Crazy Mountains*

This land area has more area represented in the warm, dry and timberline habitats than the montane area above with an estimated 5 tons per acre of large woody debris, with a range of 2.4 to 8.6. Moist, cool, cold, and wet habitat type groups make up about 44 percent of the area.

*Pryor Mountains*

This montane land area has more dominance of warm, dry habitat type groups (40 percent) with an estimated 2.8 tons per acre, with a range of 0.8 to 5.4. Moist, cool, cold, and wet habitat type groups make up about 31 percent of the area.

*Ashland District*

An estimated 2 tons per acre of large woody debris occur on this warm dry dominated habitat type group area, with a range of 1.2 to 2.9.

*Sioux District*

This warm dry habitat type pine savanna unit has the lowest large woody debris at 0.6 tons per acre, with a range of 0.2 to 1.1. Part of this is likely due to a large (65,500 acre) re-burn in 2002 that had a big impact on reducing large woody debris.

*Trend*

Large woody debris is recruited as trees die and fall and is reduced over time through decomposition or consumption by wildfire. Large woody debris is not static, it changes temporally and spatially. Pulses of large woody debris will occur and will be driven by the interactions of disturbances and drivers that effect forest vegetation (fire, insect mortality, succession, and climate). Homogeneity of forest vegetation conditions perpetuates pulses in down woody debris. A buildup of downed woody debris has likely resulted in areas especially on dry sites due to fire suppression that would otherwise have been maintained at lower levels. Recent fires across the forest that have created high mortality will see high levels of down dead material in the short term. These high levels combined with vegetation regrowth can contribute to risks of re-burn, where a loss of the large woody debris can happen. This happened in 2002 on the Sioux District in the Kraft Springs Fire, which was a re-burn of the 1988 Brewer Fire area. Near total consumption of the downed woody debris occurred in large areas of the re-burn (Sandbak 2003).

*Information Needs*

An analysis for the range of variation for large woody debris has not been completed. This would be useful for understanding the natural range of variation for down woody debris. This is an identified information gap.

**Old Growth - Amount of Old Growth (Green and others definitions)**

The concept of old growth can have different values to people. Some believe old growth is the ultimate and desirable forest condition and do not view National Forests as working forests. Others believe old growth only has value as habitat for associated wildlife species (Green et al. 1992). And others take on a

broader structural and functional characteristic view beyond just age of a forest both in individual stands and ecosystems (Kaufmann et al. 2007, Johnson et al. 1995). Structural features include large trees, wide variation in tree sizes and spacing, accumulation of large, dead standing, and fallen trees, broken and deformed tops, bole and root rot, multiple canopy layers, canopy gaps and understory patchiness. Functional characteristics involve cessation in height growth of oldest trees, near zero net productivity, and biochemistry of secondary metabolic products in old trees that may provide high resistance to insects and disease (ibid). Old growth is a late stage of succession that is important to biological diversity and is not static. As old trees die they are replaced by younger trees to restart the successional pathway to old trees.

The Forest Service views old growth as a key element in providing for biologic diversity and old growth dependent and associated species are provided for by supplying the full range of the diversity of late seral and climax forest community types (Green et al. 1992). Region 1 developed old growth types by stratifying groups of habitat types that relate closely in the environment with temperature and moisture regimes by geographic areas (ibid). Forest inventory and analysis data within the Region 1 summary database was used to estimate existing old growth across the Custer Gallatin National Forest based on the Green and others (1992) definitions.

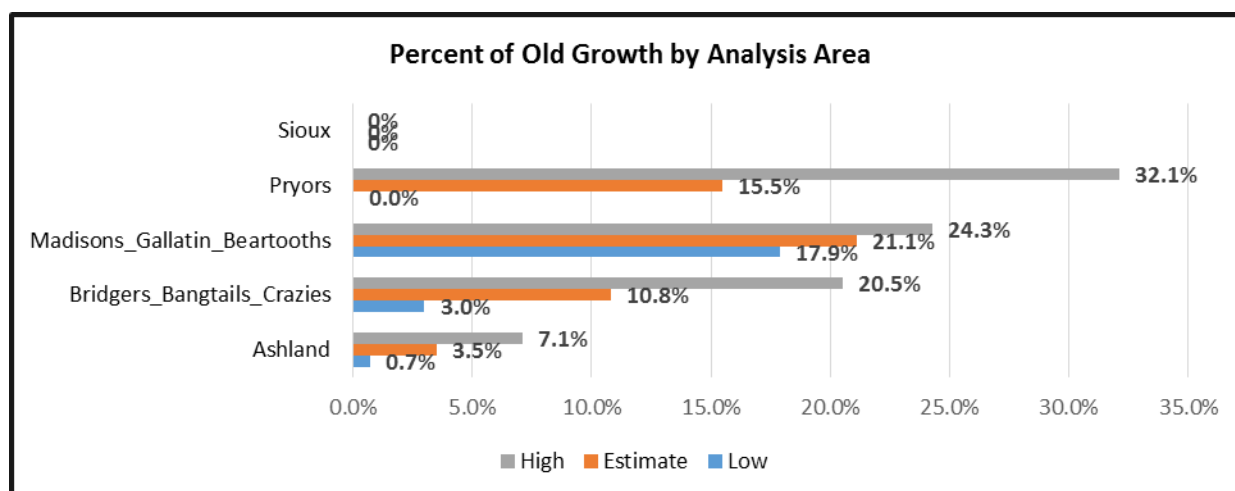


Figure 30. Percent of old growth by analysis area, R1 summary database, forest inventory and analysis plots

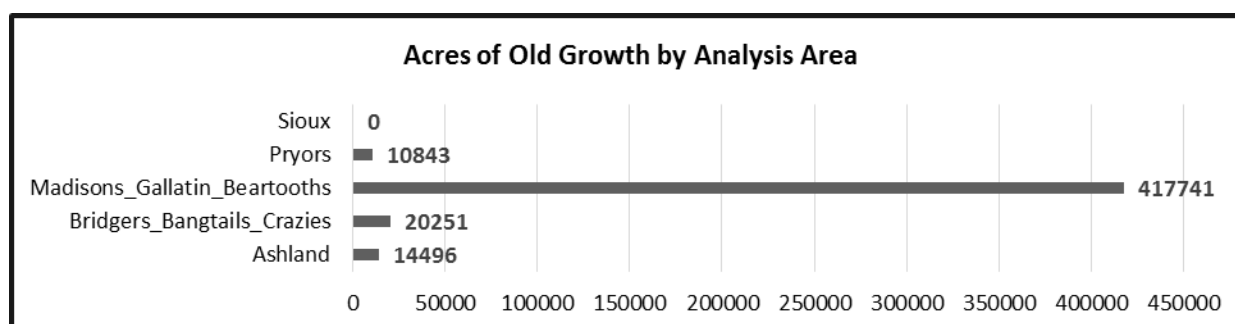


Figure 31. Estimate of acres of old growth by analysis area, R1 summary database, forest inventory and analysis plots

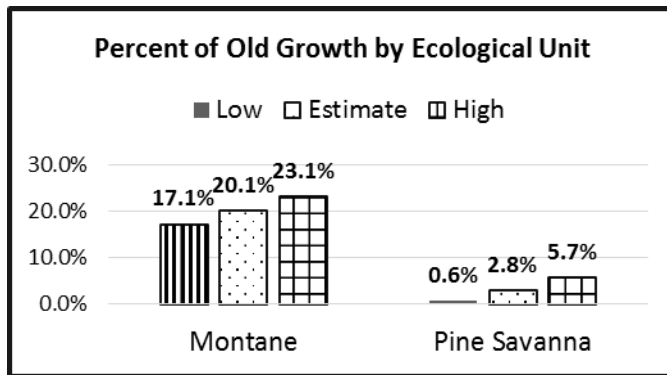


Figure 32. Percent of old growth by ecological unit, R1 summary database, forest inventory and analysis plots

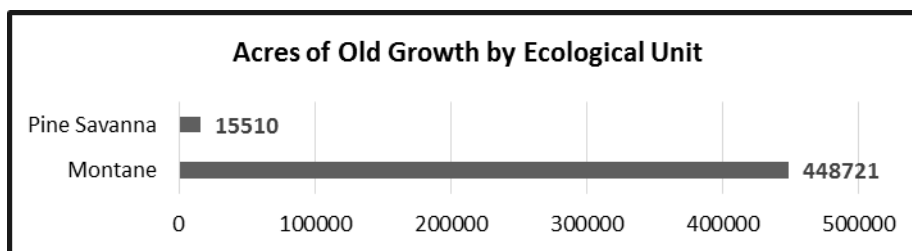


Figure 33. Estimate of acres of old growth by ecological unit, R1 summary database, forest inventory and analysis plots

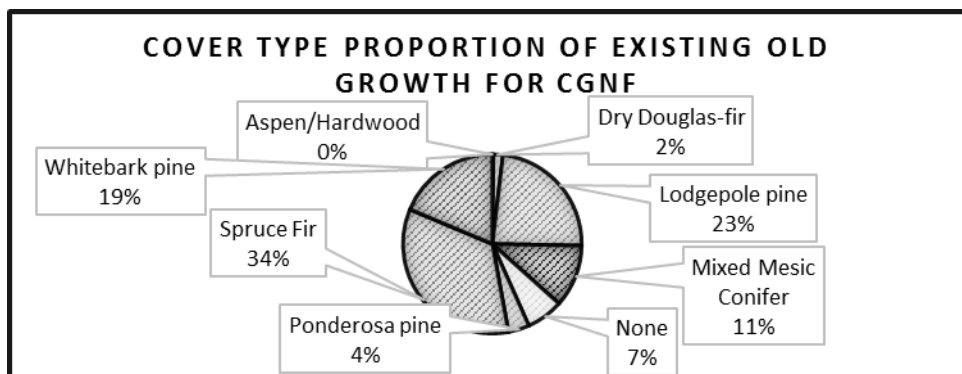


Figure 34. Cover type proportions of existing old growth on the Custer Gallatin National Forest, R1 summary database, forest inventory and analysis plots

For the Custer Gallatin National Forest analysis areas, Figure 30 to Figure 34 above show the estimated old growth at just under 23 percent of the Custer Gallatin, or 464,231 acres. The montane unit has the largest amount of estimated old growth at about 20 percent of the area or 448,721 acres. While the pine savanna unit (smaller in size) has much less of the area in old growth at 15,410 acres or about 3 percent of the area. Spruce-fire cover type has the highest amount of old growth, which is the most dominant cover type on the forest. This is followed by lodgepole pine cover type, both in estimated old growth and cover type. Whitebark pine cover type has the next highest amount of existing old growth, followed by mixed mesic conifer, ponderosa pine, and dry Douglas-fir. All the cover types except whitebark pine and ponderosa pine have estimated old growth in line with the amount of cover type representation across the forest. Ponderosa pine cover type has experienced large disturbances that

have likely reduced old growth. Whitebark pine tends to grow to older ages when disturbances are infrequent.

*Madison, Henrys Lake, Gallatin, Absaroka, and Beartooth Mountains*

This analysis area is the largest and has the highest estimate of old growth on about 417,741 acres or about 21 percent. Designated wilderness occurs only in this analysis area across 1,051,322 acres or about 49 percent of the total land area (Forest Service ownership).

*Bridger, Bangtail, and Crazy Mountains*

Acres of old growth for this land unit is 20,251 acres or about 11 percent of the analysis area.

*Pryor Mountains*

This montane unit has the least amount of estimated old growth acres at 10,843 acres. As indicated in Figure 34 above the confidence interval for this land area is wide (0 to 32.1 percent) due to the small size and fewer forest inventory and analysis plots. Intensifying the forest inventory and analysis grid, by sampling more plots would get a more reliable estimate.

*Ashland District*

This area has an estimated old growth occurring on 3.5 percent of the area or approximately 14,496 acres.

*Sioux District*

No old growth was sampled. This could be the result of three factors: 1) past and recent large fires that may have consumed old growth which then were replaced by younger trees post disturbance or 2) the land unit is divided up into 8 separate areas and the number of plots per individual land unit may not be a reliable sample or 3) past selective harvesting since late 1800s likely reduced old, large trees. Increasing the number of sample plots would help determine if old growth exists.

*Trend*

Like the other structure characteristics old growth is not static and disturbances alter, reduce, or remove old growth temporally and spatially. Trees are killed by insects, disease, windthrow, storm damage, lightning, and wildfire and then replaced by new trees. These disturbances can be small single tree mortality to large scale mortality.

Vegetation conditions exist that lend themselves to different intensities of disturbances and cycles of disturbance that determine presence and amount of old growth. Examples include: riparian areas, which are less prone to wildfire may support the development of old growth as vegetation legacy components are retained after the fire disturbance; or forested areas that are near areas that do not support the spread of wildfire (e.g. rock areas, moist meadows, water) that may promote old growth: or forested areas that are conducive to stand replacement disturbance events (fire and insects) that reduce old growth. The dryer cover types (for example, ponderosa pine and Douglas-fir) developed under a more frequent fire cycle regime (Arno et al. 1995, Tesch 1980). Historically, on these dry cover types the amount of old growth was likely higher than it is today. The frequency of disturbance likely determines the amount of old growth temporally on a landscape (Johnson et al. 1995). The majority of high elevation forests that tend to have low frequency fire cycles would likely not have been very old at a given time period. An example of this is the lodgepole pine cover types that are generally established from stand-replacement events (Arno et al. 1993).

Existing old growth has been influenced by disturbance history across the Custer Gallatin National Forest analysis areas. Lack of old growth on the Sioux District and limited old growth on the Ashland District may be due to historical logging and the large fires that have occurred on the districts since 1988. Large fires on these units are generally followed by extensive pine engraver beetle mortality 1 to 3 years post fire, further impacting large trees. Warm dry and moderately dry habitat types are generally less diverse in age on the Custer Gallatin National Forest pine savanna unit. These analysis areas have only 3 age classes, are dominated by one age class (65 to 78 percent in the 20 to 99 year old class) and 200 and older trees are uncommon. In the short term there are fewer old trees existing to develop into old growth. Barring disturbance there could be a flush of old growth in the long term. However, with frequent fire disturbances in these systems old growth will likely be impacted in the future.

Heterogeneity of age class, cover types (species composition), and structure can provide for a more stable abundance and distribution of old growth over time. The montane unit has 8 cover types that have higher diversity in existing age classes. The Bridger's, Bangtails, and Crazies and the Madison, Henrys Lake, Gallatin, Absaroka and Beartooth Mountains have 4 age classes; two dominant age classes and has representation in the 200 and older class. Barring major disturbances and as trees grow older there would likely be a more stable development of old growth over time. However, lodgepole pine cover type is common and has the second largest amount of existing old growth, which may be susceptible to insect and fire mortality. Whitebark pine cover type more recently has been impacted by the white pine blister rust and is experiencing mountain pine beetle mortality. Large fires since 1988, although not as extensive as the pine savanna unit has impacted the amount of old growth. These types of disturbance will continue to impact old growth.

The Pryor's landscape is the least diverse in age classes of the montane unit. There are 4 age classes, with 61 percent in the 20 to 99 age class with a small representation in the 200 and older class. Barring disturbances there could be an increase of old growth long term. However, this land unit has more representation of dry cover types than the rest of the montane unit and with frequent fire disturbances old growth will likely be impacted in the future.

A diversity of vegetation and conditions allow for a more stable quantity of old growth over time. Factors such as climate, fire history, insect mortality, human intervention result in homogeneity of the vegetation with less stability of old growth. Increased drought, temperature stress, and disturbance may affect old growth abundance and persistence in the future. Fire exclusion has also altered old growth. Increasing tree densities and canopy layers may have increased tree stress and vulnerability to mortality from insects, pathogens, and high intensity crown fires. If potential climate change affects disturbance probabilities in the future, landscape pattern may become the most important factor in management influences (Bollenbacher and Hahn 2008). Management in developing resilience in old growth forests to avoid losses will likely have a role and will require a solid understanding of disturbance regimes.

The current forest plans have different language for the management of old growth.

- The Gallatin National Forest Plan set a minimum of 10 percent of old growth successional stage in timber compartments containing suitable timber to achieve size and age diversity.
- The Custer National Forest Plan did not set any minimum but rather used old growth habitat for indicator species and stated the forest will provide maintenance and improvement of habitats.



Both forest plans use over mature timber in defining old growth as individual trees or stands of trees that in general are past their maximum rate in terms of the physiological processes expressed as height, diameter, and volume growth.

### *Information needs*

At the time of this assessment there is no quantitative assessment for natural range of variability of old growth. The SIMPPLLE model is being used to provide a range of what the natural abundance of old growth may have been and then compare it to the existing condition. When this is complete, it will be used in addition to information presented above to further assess ecological integrity for this key ecosystem characteristic.

Another, less critical need is to spatially intersect the forest inventory and analysis plots with the wilderness boundaries to discern if there could be a loss of old growth and large trees attributed to early harvest practices, land conversions, and disturbances or if these actions may have been tempered by actions such as fire suppression which preserved old growth that may otherwise have burned.

## **Connectivity**

### **Existing Condition**

Spatial patterns of vegetation on the landscape is important because it affects ecological processes, including wildlife and plant dispersal and is one of the most complex attributes of ecosystems to quantify. Historically, forests were spatially heterogeneous at multiple scales as a result of interactions among succession, disturbance, and other processes. For example, tree neighborhoods nest within successional patches, which nest within local landscapes. Altered disturbance regimes have led to increased homogeneity in terms of vegetation structure, composition, and the spatial patterning of patches across the landscape (Hessburg et al. 2015). Risk and the extent of area impacted by disturbance processes such as fire and insect or disease activities may be driven by the spatial pattern of vegetation on the landscape. Topography, soils, variation in precipitation, wildfires, and human activities (wildfire suppression and vegetation treatments) and development (roads, trails, wildland urban interface) can also affect the connectivity of forests. The appropriate mosaic of vegetation types and conditions that make up a resilient and functioning landscape is likely driven by how they are connected and the pattern they have on the landscape. The ultimate goal of understanding connectivity and pattern is to better understand the appropriate mosaic of conditions that make up a resilient and functioning landscape. Understanding the existing composition, structure and function and the natural range of variability of these will assist land managers in this effort.

Heterogeneity refers to the uneven distribution of various concentrations of different composition and structure attributes of vegetation types or cover types occurring on the landscape. Heterogeneity in forested landscapes can generally be characterized where a variety of patch sizes of early seral to late seral vegetation in various structure stages occurs. Homogeneity on the other hand is the opposite, such as where fires have been excluded and large forested landscapes have become dominated by shade tolerant species with high tree densities and multiple-layer canopy structures. Heterogeneity generally reduces the extent of disturbances such as fire and insect outbreaks on the landscape (Hessburg et al. 2015). Heterogeneity on forest landscapes may occur as mosaics of patches generated by many events, or they may be created by single large events that occur infrequently (Kashian et al. 2005). And pre disturbance vegetation patterns may have implications on future vegetation patterns (ibid). Landscape heterogeneity is important in the Greater Yellowstone Ecosystem and thus also key for sustainability of an array of ecosystem services, including primary production, carbon storage, timber

production, and wildlife habitat (Turner et al. 2012). Land managers can intervene to sustain these ecosystem services, however there is no optimal landscape mosaic that will increase all these services because landscapes are dynamic and unique (ibid).

Resilient landscapes are generally made up of mosaics of age classes, composition, structures, and successional stages. This variability ensures that not all areas are equally susceptible to the same drivers at the same time. Spatial heterogeneity in terms of the key ecosystem components described above for this assessment are influenced by interrelated ecosystem drivers, and this will have implications for important ecosystem services such as reforestation, timber productivity, wildlife habitat quality, watershed health, and carbon storage (Turner et al. 2012).

Biodiversity and genetic flow of plant material across the landscapes will be important for adaptability of vegetation for the projected future conditions; making connectivity and spatial pattern of the vegetation important. Additionally things like seed dispersal strategies, e.g. the ability of species to establish on sites after disturbance (i.e. lodgepole pine cone serotiny or the 50-year lag time for cone production in limber pine or the non-wind disseminated seed or the Clark's nutcracker role), will depend on spatial heterogeneity and the suitability of future site conditions including climate conditions and the characteristics of microsites. Genetic diversity influences adaptability of plants to changing conditions and by maintaining a diverse and robust genetic base resiliency can be promoted. Resilience of vegetation in changing conditions will be aided by maintaining a robust genetic base as genetic diversity has an important influence on the ability of plants to adapt to changing conditions. Tree improvement programs that include collection of genetic plant materials and out-planting test plantations play an important role in understanding the genetics of populations (Scott et al. 2013). Participation in these type of programs, such as the regional WBP genetic restoration program in the Greater Yellowstone Area will help predict impacts of climate change on forest vegetation and assist managers for options to respond to climate change (ibid).

Many elements of composition and structure could be assessed as a means to understand landscape heterogeneity. Forest openings is one the assessment team identified as the key ecosystem characteristic for forest vegetation connectivity (pattern). Roads, trails, and human developments were deemed more important for connectivity and are discussed in other sections of the assessment. The Region 1 existing vegetation database was used to assess forest openings. Two classifications were looked at: transitional forest (forested areas impacted by disturbance not reestablished in forest cover) and early successional forests (seedling sapling size - 0 to 4.9 inches) - that have had forest cover reestablished to determine the pattern of forest openings from stand replacement disturbances. The following attributes were summarized and are displayed in the Table 12 below:

- Patch dynamics of forest openings - Abundance, average and range of the sizes of early successional forest patches created by stand-replacing disturbance for transitional and seedling/sapling size classes.

Additional elements of structure and composition were considered for forest vegetation connectivity but cannot be addressed with the data and analysis tools available at the writing of this assessment. However, the importance of these are addressed briefly and identified as data gaps.

- Patch dynamics of multi-storied structure: Amount and extent of two-story, three-story and continuous patches.
- Ecosystem connectivity: Average and range of connected patch sizes by cover type; including by size class and density.

## Forest Openings

Forest openings are a strong contrast to the adjacent mid or late successional forest. These openings provide habitat for many wildlife species due to the forest “edge” effect which has a different composition and vegetation structure that some wildlife depend on. Openings in the forest created by stand-replacement disturbances are distinct and one of the easiest forest structures on the landscape to detect. Forest reestablishment post disturbance, is the starting point in forest successional development and this sets the stage for the pattern of the future forest. Understanding the size of openings that can be expected under a natural disturbance regime is important for management purposes. Under the current forest plans, size of openings is not defined as what may occur within a natural range of variability. Understanding this would give options such as maximum size of harvest openings to managers.

A natural range of variability analysis of the extent, size and abundance of forest openings is currently not available and is identified as an information need. Estimating these metrics for each forest type or habitat type group will assist the forest plan process. Comparing these openings metrics to existing openings may help inform plan components in the revision process. An analysis of the existing openings (for all forest types) using the Region 1 existing vegetation database found the following (see Table 12 below and maps Figures 99 through 103 in appendix A):

**Transitional Forest** – Areas forested prior to disturbance not currently reestablished with forest cover largely due to wildfires (see Shea 2016 for extent and years of wildfire occurrence). Minor acreage is due from recent harvest and prescribed burning, see “Vegetative Treatment” section for acres that have had recent regeneration harvests and prescribed burning.

- Forestwide 275,246 acres are in post disturbance openings. There are 4,876 patches with an average size of 57 acres and the maximum at 42,551. The majority of these are the result of wildfires over the last 15 years.
- Ashland: Large portions of this land unit have not returned to forest cover post wildfires since 2000. There are 82,126 acres in this state. The average patch size is 40 acres with the largest at 6,651. There are 2,059 patches. About 28 percent of the potential forested acres are in this state.
- Bridgers Bangtails Crazies: This land unit has the second least amount of acres in this transitional state at 3,506 acres due from recent wildfires (approximately 2 percent of the total potential forested acres). There are 222 patches averaging 16 acres in size with the largest at 611 acres.
- Madison, Henrys Lake, Gallatin, Absaroka, and Beartooth Mountains: The highest amount of acres largely due to wildfires is in this land unit at 180,505 acres. The 2,477 patches average 73 acres and largest is 42,551 acres. About 11 percent of the total potential forested acres in this land unit are in this state.
- Pryors: Has the least amount of acres in this transitional state at 2,936 acres (approximately 6 percent of the total potential forested acres). This acreage is due to the 2002 Red Waffle Fire. There are 14 patches averaging 210 acres with the largest at 2,685 acres.
- Sioux: This unit has 33,293 acres in this state largely due to the 2012 Dugan Draw wildfire. There are 95 patches averaging 65 acres with the largest at 2,554 acres.

**Early Successional Forest** – Areas forested prior to disturbance currently reestablished with forest cover and in the early successional state. Across the Custer Gallatin, these include older wildfire areas (see “Fire/Fuels” section of assessment for extent and years of wildfire occurrence) as well as harvested

acres and prescribed fire acres in the last 30 years, see “Vegetative Treatment” section for acres that have had recent regeneration harvests and Maps A1.11 to A1.15 Fuels and Harvest Treatments in appendix A.

- **Forestwide:** Early successional forests which are mapped in the Region 1 existing vegetation database as seedling/saplings are present across 76,953 acres on 5,521 patches, with an average size of 14 acres and a maximum size of over 2,138 acres.
- **Ashland:** There is 1,384 acres in this state. The average patch size is 5 acres with the largest at 17 across 270 patches. Less than 1 percent of the potential forested acres are in this state.
- **Bridgers Bangtails Crazies:** This land unit has the second highest amount of acres in early successional state at 7,349 acres (approximately 4 percent of the total potential forested acres). There are 638 patches averaging 12 acres in size with the largest at 168 acres.
- **Madison, Henrys Lake, Gallatin, Absaroka, and Beartooth Mountains:** The highest amount of acres is in this land unit at 65,553 acres. The 4,433 patches average 15 acres and largest is 2,138 acres. About 4 percent of the total potential forested acres in this land unit are in early successional status.
- **Pryors:** Has 2,936 acres (approximately 6 percent of the total potential forested acres) in early successional status. This acreage is due to the 2002 Red Waffle fire. There are 162 patches averaging 16 acres with the largest at 402 acres.
- **Sioux:** This unit has the least amount of acres at 66. There are 8 patches averaging 4 acres with the largest at 8 acres.

Patch sizes of both transitional forest and early successional forest are variable in shape. Smaller patches are generally attributable to mountain pine beetle, high-severity fire, or harvest. Large patch size is the largely the result of wildfire. Please refer to maps Figures 99 through 103 in Appendix A, Tree Size Class and Transitional Forest.

**Table 12. Transitional forest patch size by analysis area, VMap**

<b>Transitional Forest by Landscape Area</b>	<b>Sum Acreage</b>	<b>No. of Patches</b>	<b>Average Size</b>	<b>Maximum Size</b>	<b>Min Size</b>
Ashland	82126	2059	40	6651	<1
Bridgers, Bangtails, Crazies	3,506	222	16	611	<1
Madison, Henrys Lake, Gallatin, Absaroka and Beartooth Mtns	180,505	2477	73	42,551	<1
Pryors	2,936	14	210	2,685	<1
Sioux	33,293	987	34	16,730	<1
Grand Total	302,366	5,759	52	42,551	

**Table 13. Seedling and sapling patch size by analysis area, VMap**

<b>0-4.9 Tree Size by Landscape Area</b>	<b>Sum Acreage</b>	<b>No. of Patches</b>	<b>Average Size</b>	<b>Maximum Size</b>	<b>Min Size</b>
Ashland	1,384	270	5	17	<1
Bridgers, Bangtails, Crazies	7,349	638	12	168	<1
Madison, Henrys Lake, Gallatin, Absaroka and Beartooth Mtns	65,553	4,433	15	2,138	<1

<b>0-4.9 Tree Size by Landscape Area</b>	<b>Sum Acreage</b>	<b>No. of Patches</b>	<b>Average Size</b>	<b>Maximum Size</b>	<b>Min Size</b>
Pryors	2,602	162	16	402	<1
Sioux	66	18	4	8	<1
Grand Total	76,953	5,521	14	2,138	

### *Multi-Storied Patches*

Vertical structure class provides presence of multi-storied conditions (single, two, three, or continuous canopy layers). However, our current vegetation layer (Region 1 existing vegetation database – VMap) uses remote imagery and understory conditions are not discernable, so we are currently unable to map this. Although forest inventory and analysis plot data provides this information, we would need to undergo a vigorous analysis process to determine if it could reliably be attributed to our spatial polygons. This is an identified data gap and likely will not be available for the revision process.

### *Ecosystem Connectivity*

The spatial distribution of combinations of cover types, size classes, and tree densities is important for disturbance processes, genetic flow, and wildlife habitat. An analysis of this type is not available at this time. This is identified as a critical data gap.

### *Trend*

The pattern of vegetation present on the landscape today has been influenced by several factors including climate, disturbance regimes, and human management. Currently little is known regarding the historic patch and pattern of forest openings, multi-storied patches, and ecosystem connectivity for the Custer Gallatin until a more detailed natural range of variability analysis can be conducted.

Forest harvesting on the national forests in the Greater Yellowstone Area during the mid-20<sup>th</sup> century led to a patchwork mosaic of small, dispersed clearcuts in some areas (Turner et al. 2012). In other areas, with succession and fire exclusion, there likely has been a general trend of an increasing homogeneous pattern of forest structure. Perhaps the most documented and studied effect of fire exclusion is the change in stand composition and structure (Keene et al. 2002). In general, forest composition has gone from early seral, shade-intolerant tree species to late seral, shade tolerant species, while stand structure has gone from single-layer canopies to multiple-layer canopies with fire exclusion (ibid).

Climate models that predict rapidly warming temperatures have a high degree of uncertainty (USDA 2015b). The complexity of ecosystems and being able predict how forest vegetation and these systems may respond to highly uncertain climate change further adds to the level of uncertainty (ibid). Climate effects will present itself different ways on different landscapes and it will be important to consider climate effects within prescriptions and implement adaptive management at the local levels. There will be no “one size fits all” approach. Warming conditions may increase the extent and severity of natural disturbances, which may increase the patch size and connectivity of early seral forest openings and increase the amount of edge in the landscape pattern. Large continuous areas of multi-storied forests may have actually been promoted in the current condition by fire suppression (Keene et al. 2002). If larger more severe fires occur there could be consequences for genetic diversity and reforestation opportunities where certain vegetation cannot adapt. Spatial heterogeneity will play particularly important roles for the production of wildlife habitat, with thresholds in habitat quality, habitat connectivity, and/or patch size apparent for many species (Turner et al. 2012).

### Information Needs

Analysis of average, range, and patch size of existing, potential vegetation types, as well as combinations of cover types, size classes, and tree densities would assist in understanding ecosystem connectivity. The potential for more sophisticated landscape ecology metrics should be assessed to answer the questions regarding ecosystem connectivity. Additional analysis of patch configuration by potential vegetation or cover type would be beneficial to determine the extent and the pattern within vegetation types. This has not been done at the time of writing this report and is a data gap.

Development of an attributed spatial layer with plot data would be helpful to look at landscape patterns of multi-story forested conditions and would also be beneficial, however this likely cannot be done for this forest plan revision effort. Future use of LIDAR (Light Detection and Ranging – a surveying technology) could analyze for multistory conditions and assist future planning. This is also an identified data gap.

A SIMPPLLE analysis is being conducted to provide a natural range of variation on forest openings on the metrics used above for existing conditions and will be added to this assessment when compiled. These metrics could then be compared to get an understanding of the natural range of variation by vegetation type and analysis area and would help inform our understanding of appropriate harvest size limits. Incorporating climate scenarios in the modeling will help inform expected trends. Further assessment of the SIMPPLLE model is needed to determine if metrics can be derived to questions regarding ecosystem connectivity.

## Ecosystem Diversity: Key Characteristics by Potential Vegetation Types

### Existing Condition

For the forest plan revision process, it may be useful to apply certain key characteristic components to broad potential vegetation groups. Following is an analysis of existing condition for each forested habitat type groups found on the Custer Gallatin National Forest to provide data for future analysis. Age class, although not an identified key ecosystem characteristic, is included in this discussion for assisting in understanding old growth amounts and distribution across the habitat type groups. Table 14 displays the proportion of the habitat type group by the 2 analysis areas. As the table depicts, not all habitat type groups occur on both analysis areas.

**Table 14. Percent R1 habitat type group by ecological unit, R1 summary database, forest inventory and analysis plots**

Habitat Type Group	Montane	Pine Savanna
Cold	28.68%	0.00%
Cool Mod Dry to Moist	19.07%	0.00%
Cool Moist	6.40%	0.00%
Cool Wet	4.77%	0.00%
Hot Dry	3.38%	0.00%
Mod Warm Dry	12.53%	18.50%
Timberline	8.11%	0.00%
Warm Dry	2.18%	48.42%
Non -forested	14.88%	33.08%
Total	100%	100%

### Hot Dry Habitat Type Group

This is the driest forested habitat type group where limber pine is generally the climax species. These sites are adjacent to grasslands/shrublands. Dominant species may include limber pine, juniper, Douglas-fir and ponderosa pine. Lodgepole pine may be present, but is rare on these types. Less than 4 percent of the forested area falls in this habitat type group on the montane unit. There are 47 forest inventory and analysis sub plots on the montane unit and 0 on the pine savanna unit classified in this group. The montane unit has about 3 percent of the area in this group.

### Composition

Non-forested or savannah conditions dominate this type, which is not surprising due to nature of these forested settings being transitional post disturbance when seed source is removed and/or drought conditions limit tree reestablishment. Dominant cover types include the species that can survive on the driest sites (ponderosa pine, limber pine, juniper, and Douglas-fir). Fire suppression may have allowed Douglas-fir colonization and establishment (dry Douglas-fir and mesic conifer) on the montane analysis area that would otherwise had been prevented with the frequent fires. Aspen hardwood cover types are confined to moist areas.

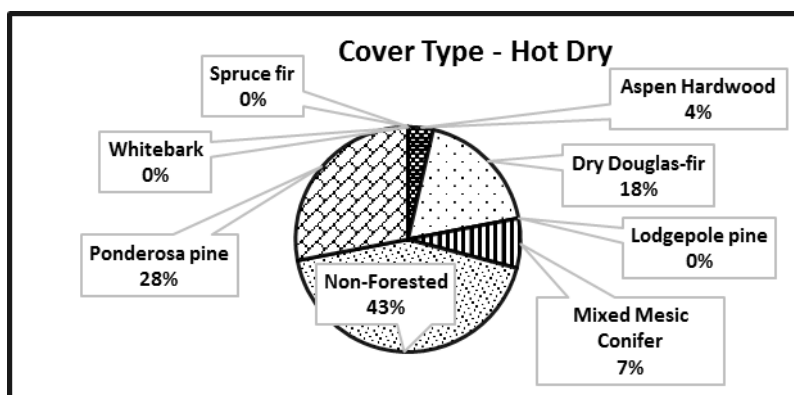


Figure 35. R1 cover type by proportion of habitat type group for Custer Gallatin National Forest, R1 summary database, forest inventory and analysis plots

Three of the species of interest are present in the hot dry habitat types. As expected, limber pine has the highest presence in this group and only occurs on the montane unit. Juniper is a common associate in these types and aspen is found where soils are moist, generally where recent disturbances have occurred, and sunshine is plentiful. Juniper has the second highest presence.

Table 15. Presence of individual species of interest; proportion of hot dry habitat type group for Custer Gallatin National Forest, R1 summary database, forest inventory and analysis plots

Paper birch	Green ash	Juniper	Whitebark pine	Limber pine	Cottonwood	Aspen
0.0%	0.0%	16.1%	0.0%	41.1%	0.0%	3.6%

### Structure

Currently non-forested or sparsely forested (less than 10 percent canopy cover) are common in this habitat type group. Small and medium tree classes are dominant with limited very large tree class. No forest inventory and analysis plots were classified in the large tree class. Fifty two percent of the plots

were classified with less the 10 percent canopy cover. Thirty three percent were classified with moderate/high or high density class and 15 percent a low or moderate. Single story structure is most common (45 percent), followed by continuous (9 percent), and 3 percent in 2-storied structure.

No old growth was classified in the hot dry habitat type group. The majority of the sites are under 100 years old with 9 percent in the 100 to 199 age class. Slow tree reestablishment is indicated by 2 percent in the seedling/sapling tree class (less than 20) and the current high amount of non-forest condition. No sites were classified in the 200 plus age class.

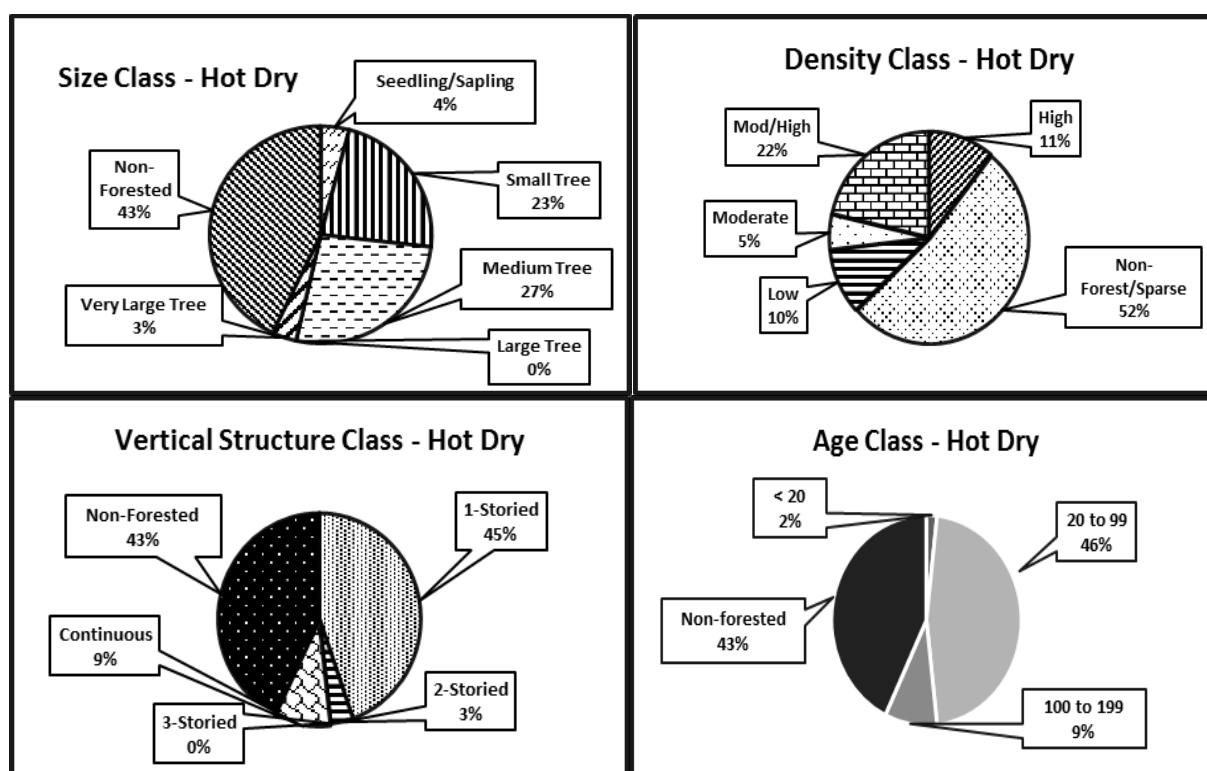


Figure 36. Size class, density class, vertical structure class, and age class in the hot dry habitat type group, forest inventory and analysis data, R1 summary database

Medium snags are most common as is the similar trend in both the montane and pine savanna unit. Very large snags estimated at 0.43 per acre in this group and above the average in the pine savanna unit and are below the average in the montane unit. Estimated large snags of 0.43 per acre are below the average in the pine savanna and montane units.

Table 16. Estimates of snags per acre on the hot dry habitat type group for Custer Gallatin National Forest, R1 summary database, forest inventory and analysis plots

Medium	Large	Very Large
2.58	0.43	0.43

Large woody debris is estimated at 1.8 tons per acre. These hot dry sites would be expected to have low levels and is below the average for the montane unit and the same for the pine savanna unit.



## Function

Forest insects and diseases are important disturbance factors in forest ecosystems. Insect and disease activity may dramatically alter the structure, composition, and age class distribution of forested stands and may influence a manager's ability to achieve desired ecological conditions. Forest insects require three things to cause significant impact to resource values: susceptible hosts; insect populations; and favorable weather conditions. Hazard rating systems measure the susceptibility of forested areas to a particular insect by evaluating the amount of susceptible host. High and moderate hazard forested areas are more likely to experience significant mortality if insect populations are present and the weather is favorable.

Over 50 percent of the plots had no hazard for the insects of interest. High hazard only exceeds 14 percent for the combined beetle and western spruce budworm. Where Douglas-fir is dense and multi storied, spruce budworm has been assessed a moderate and high hazard (32.8 percent). Less than 26 percent has a moderate and high hazard for the Douglas-fir beetle. Lodgepole pine, a minor component in this type, also has a low hazard. Moderate to high hazard for mountain pine beetle was assessed on 7.2 percent for ponderosa pine. When assessing combined beetle hazard for limber pine, ponderosa pine, and lodgepole pine the moderate and high hazard was 32.8 percent of the plots.

**Table 17. Insect hazard ratings; proportion of the hot dry habitat type group for Custer Gallatin National Forest, R1 summary database, forest inventory and analysis plots**

Insect	No Hazard	Low Hazard	Moderate Hazard	High Hazard
Douglas-fir beetle	56.5%	17.9%	23.8%	1.8%
Combined beetle <sup>1</sup>	52.4%	14.9%	18.5%	14.3%
Mountain pine beetle – lodgepole pine	92.9%	5.4%	1.8%	0.0%
Mountain pine beetle – ponderosa pine	92.9%	0.0%	1.8%	5.4%
Western spruce budworm	56.5%	10.7%	18.5%	14.3%

<sup>1</sup>Combined beetle includes mountain pine beetle (*Dendroctonus ponderosae*) and pine engraver beetles (*Ips* species). Hazard rating is for lodgepole pine, limber pine, whitebark pine, and ponderosa pine when present.

## Connectivity-Pattern

An analysis for stand replacing disturbance pattern is currently being conducted using the SIMPPLLE model to determine a natural range of abundance and an average range of patch sizes. Considering the high frequency, low severity fire regime one would expect a small patch size. Analysis of existing patch size post disturbance using the Region 1 existing vegetation database that focused on the small size class (early successional forest) and transitional forest attributes was discussed earlier (see Forest Openings). Patch size metrics for this habitat type group include (Table 63 and Table 64 in appendix A):

- Bridgers, Bangtails, Crazies
  - ♦ Early Successional Forest - There are 5 acres in this state. The average patch size is 2 acres with the largest at 2 across 3 patches.
- Madison, Henrys Lake, Gallatin, Absaroka, and Beartooth Mountains
  - ♦ Transitional Forest –393 acres. The average patch size is 9 acres with the largest at 38 across 45 patches.

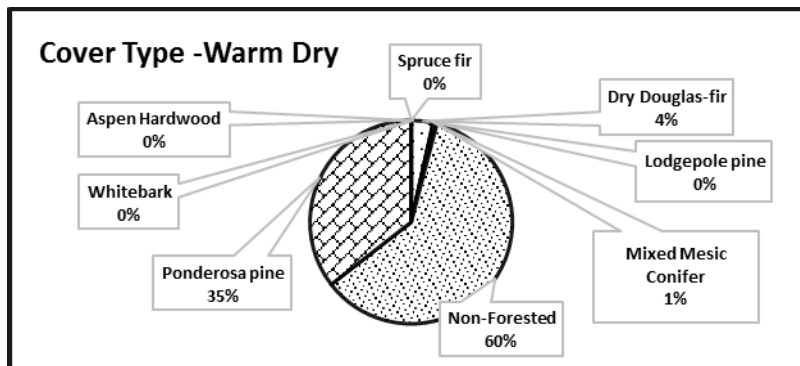
- ♦ Early Successional Forest - There are 451 acres in this state. The average patch size is 10 acres with the largest at 66 across 46 patches.
- Pryors
  - ♦ Transitional Forest – There are 7 acres in this state. The average patch size is 4 acres with the largest at 6 across 2 patches.
  - ♦ Early Successional Forest - 51 acres. The average patch size is 5 acres with the largest at 11 across 11 patches.

### *Warm Dry Habitat Type Group*

About 2 percent of the montane unit and 48 percent of the pine savanna unit is represented by this warm dry habitat type group. This group has 217 forest inventory and analysis sub plots (31 montane, 186 pine savanna). These are ponderosa pine or dry Douglas-fir climax types. With frequent natural disturbance, open-grown conditions with bunchgrass understories prevail. The driest of the Douglas-fir habitat types occur in this group. Only ponderosa pine cover type occur on the pine savanna unit.

### **Composition**

This is the most dominant occurring habitat type group on the pine savanna unit and a minor presence on the montane unit. Similar to the hot dry type, this group is dominated by species that occur in dryer settings (ponderosa pine and Douglas-fir). Ponderosa pine cover type is dominate with limited presence of Douglas-fir cover types (dry Douglas-fir, mixed mesic conifer) on the montane unit. Sixty percent of the warm dry type is currently dominated by non-forested or sparsely forested (less than 10 percent canopy cover) conditions due to large stand replacing fires since 2000. Frequent low severity fires would be more typical in these types. With fire suppression, drought, and climate change, these types have experienced large fires that have removed seed sources. Ashland and Sioux Districts have large areas of potential ponderosa pine sites currently non-forested. Portions of the non-forested types that are currently dominated by grasses and shrubs are expected to be in a transitional state for longer than expected period, unless artificially reforested.



**Figure 37. R1 cover type by proportion of habitat type group for Custer Gallatin National Forest, R1 summary database, forest inventory and analysis plots**

Three of the species of interest occur in this type. Limber pine is a minor component in this type and is present on the montane unit. Green ash is present but only on the pine savanna unit within and adjacent to woody draws. Juniper is a common associate in these types and has the second highest presence across all habitat type groups.

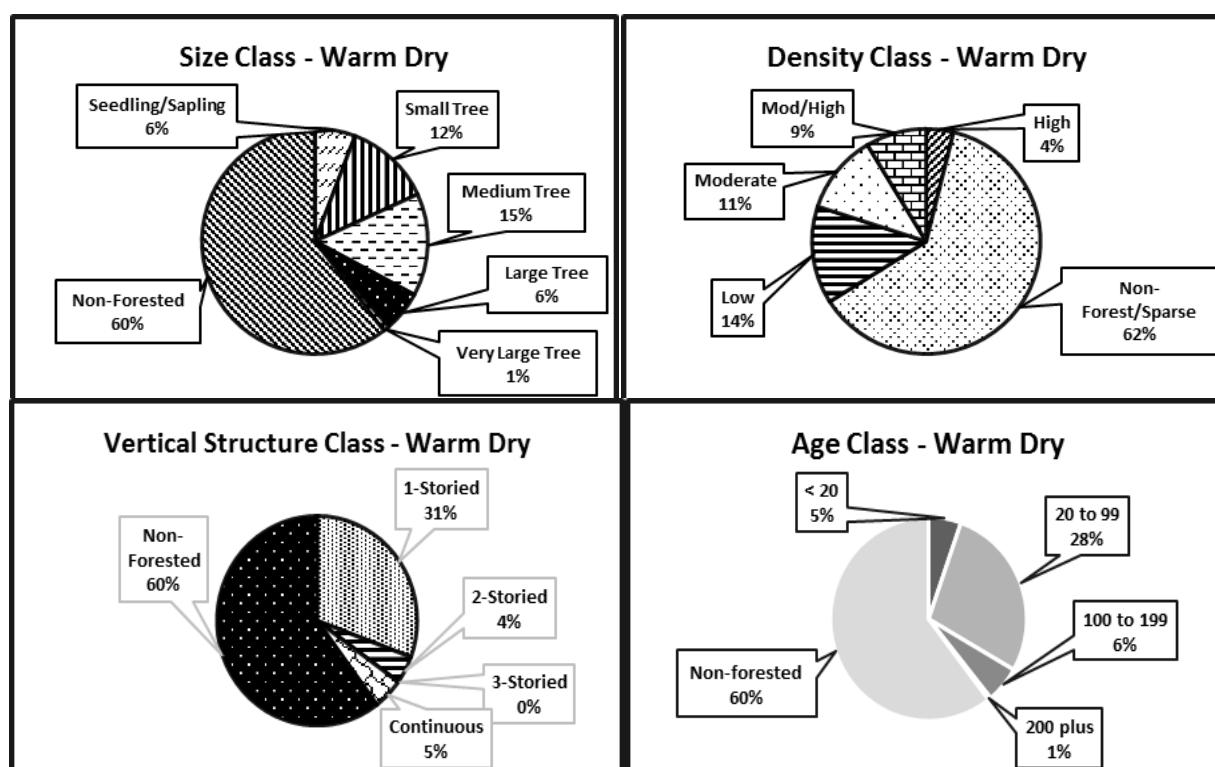
**Table 18. Presence of individual species of interest; proportion of the warm dry habitat type group for Custer Gallatin National Forest, R1 summary database, forest inventory and analysis plots**

Paper birch	Green ash	Juniper	Whitebark pine	Limber pine	Cottonwood	Aspen
0.0%	0.4%	15.8%	0.0%	2.2%	0.0%	0.0%

### Structure

All five size classes are represented with small and medium size most dominant. Seedling/sapling and large tree classes are equal and very large tree class is rare at 1 percent. Sixty two percent of the plots were classified with less than 10 percent forested density class. Thirteen percent have moderate/high or high density class and twenty five percent moderate and low. Single-story structure dominants this type with 2-storied and continuous less common.

The lowest estimate of old growth occurs in this habitat type group at 1.8 percent, likely having been reduced by recent large fires. The majority of the age class is less than 100 years. These sites are slowly reestablishing with forest cover as evidenced by 5 percent in the less than 20 year old class. The 200 plus class is rare at 1 percent.



**Figure 38. Size class, density class, vertical structure class, and age class in the warm dry habitat type group, forest inventory and analysis data, R1 summary database**

Medium size snags dominate this group as well. Large snags are estimated at 1.05 per acre and very large at 0.02. Very large snags are rare and below the estimated average for the montane and pine savanna units. Large snags are lower than the average in the pine savanna unit and in the montane unit.

**Table 19. Estimates of Snags per acre on the warm dry habitat type group for Custer Gallatin National Forest, R1 summary database, forest inventory and analysis plots**

Medium	Large	Very Large
5.90	1.05	0.02

Like the hot dry group with a frequent low severity fire regime, low amounts of large woody debris would be expected. Downed large woody debris is estimated at 1.8 tons per acre, slightly above the average for the pine savanna unit and below the average for the montane unit. As dead trees continue to fall on these sites in the 2012 and later fires, these tonnages are likely to increase.

### Function

No hazard was assessed for the insects of interest on over 57 percent of the plots. Douglas-fir beetle and western spruce budworm are both assessed the same hazards that are relatively low, likely due to the host species being minor components. About 33 percent of the ponderosa pine have moderate and high hazard to mountain pine beetle. Combined beetle hazard has the largest amount of high hazard at 12.2 percent.

**Table 20. Insect hazard ratings; proportion of the warm dry habitat type group for Custer Gallatin National Forest, R1 summary database, forest inventory and analysis plots**

Insect	No Hazard	Low Hazard	Moderate Hazard	High Hazard
Douglas-fir beetle	94.0%	2.9%	1.8%	1.3%
Combined beetle <sup>1</sup>	57.1%	9.8%	21.0%	12.2%
Mountain pine beetle – lodgepole pine	100.0%	0.0%	0.0%	0.0%
Mountain pine beetle – ponderosa pine	59.6%	7.5%	26.7%	6.3%
Western spruce budworm	94.0%	2.8%	1.8%	1.3%

<sup>1</sup>Combined beetle includes mountain pine beetle (*Dendroctonus ponderosae*) and pine engraver beetles (*Ips* species). Hazard rating is for lodgepole pine, limber pine, whitebark pine, and ponderosa pine when present.

### Connectivity-Pattern

An analysis for stand replacing disturbance pattern (patch size) is currently being conducted using the SIMPPLLE model to determine a natural range of abundance and an average range of patch sizes. Considering the high frequency, low severity fire regime one would expect a small patch size. Analysis of existing patch size post disturbance using the Region 1 existing vegetation database that focused on the small size class (early successional forest) and transitional forest attributes was discussed earlier (see Forest Openings). Patch size metrics for this habitat type group include (Table 63 and Table 64 in appendix A):

- Ashland
  - ♦ Transitional Forest – 82,126 acres. Average patch size 40 acres, largest 6,651 acres across 2,059 patches.
  - ♦ Early Successional Forest - There are 1,384 acres in this state. The average patch size is 5 acres with the largest at 17 across 270 patches.
- Bridgers, Bangtails, Crazies

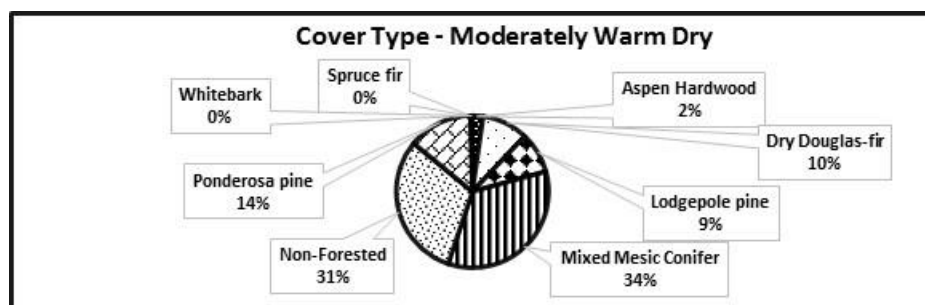
- ♦ Early Successional Forest - There are 6 acres in this state. On the ponderosa pine potential vegetation sites, there is one patch at 3 acres. The Douglas-fir potential vegetation sites have an average patch size of 1 acre, largest 2 acres across 3 patches.
- Madison, Henrys Lake, Gallatin, Absaroka and Beartooth Mountains
  - ♦ Transitional Forest – 4,592 acres. On the ponderosa pine potential vegetation sites, the average patch size is 8 acres largest 29 acres across 17 patches. The Douglas-fir potential vegetation sites have an average patch size of 14 acres, with largest at 239 acres across 313 patches.
  - ♦ Early Successional Forest - There are 297 acres in this state. On the ponderosa pine potential vegetation sites, the average patch size is 4 acres largest 7 acres across 2 patches. The Douglas-fir potential vegetation sites have an average patch size of 6 acres, with largest at 31 acres across 45 patches.
- Pryors
  - ♦ Transitional Forest – 5 acres. Average patch size 3 acres, largest 3 acres across 2 patches.
  - ♦ Early Successional Forest - There is one patch at 5 acres.
- Sioux
  - ♦ Transitional Forest – 33,293 acres. Average patch size 34 acres, largest 16,730 acres across 987 patches.
  - ♦ Early Successional Forest - There are 66 acres in this state. The average patch size is 4 acres with the largest at 8 across 18 patches.

#### *Moderately Warm Dry Habitat Type Group*

There are 188 forest inventory and analysis sub plots on the montane unit and 72 on the pine savanna unit classified in this group. About 13 percent of the montane unit and 18 percent of the pine savanna unit are represented by this group. These are moist Douglas-fir and ponderosa pine climax sites with grass and shrub understories. With frequent disturbance these sites can be maintained in open grown Douglas-fir or ponderosa pine. Stands become dense without disturbance. A mix of lodgepole pine can occur on the montane unit. The pine savanna unit only has ponderosa pine habitat types with no Douglas-fir is present.

#### **Composition**

This is the last of the habitat type groups that occur on the pine savanna unit. This more moist type supports domination of Douglas-fir overtime without disturbance on the montane unit. Lodgepole pine cover type is present only the montane unit. Ponderosa pine cover type is common at 14 percent and is the only conifer cover type on the pine savanna unit. Ponderosa pine cover type under natural disturbance regimes would be expected to have a higher representation on the montane unit. Douglas-fir dominates in this habitat type group (44 percent - dry Douglas-fir and mixed mesic conifer). Non-forest types are represented on about a third of the area. Recent fire areas are dominated by grass and shrubs and are still recovering to forest cover. Aspen/hardwood cover type is present in small amounts at 2 percent and generally confined to the moister /wetter areas, woody draws and post disturbance areas. Because of the moist conditions, this group supports more diversity of tree species than all other warm/dry types.



**Figure 39. R1 cover type by proportion of habitat type group for Custer Gallatin National Forest, R1 summary database, forest inventory and analysis plots**

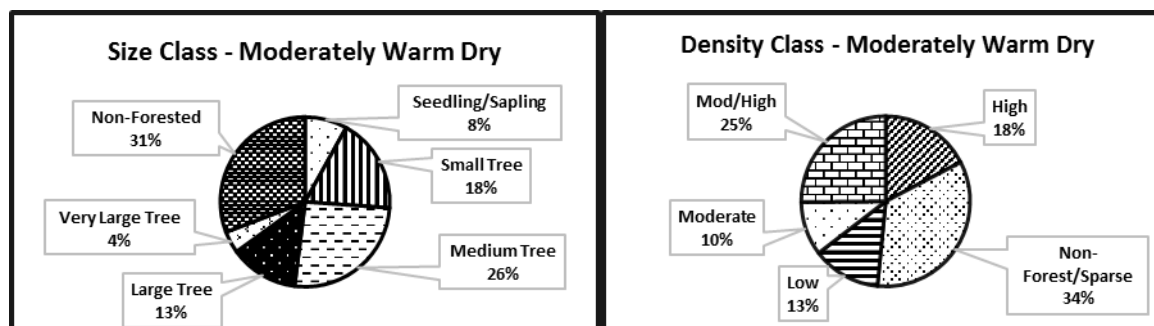
Six of the seven species of interest are present in this habitat type group. Although whitebark pine is present in small numbers, it would not be expected to compete well in warm dry conditions. Green ash has the largest presence in this habitat type group, occurring only on the pine savanna unit. Juniper and limber (montane unit only) are minor associates on the dryer sites. Paper birch although not sampled by the forest inventory and analysis plots, is known to exist on the Sioux Ranger District. Presence is very rare and only 4 small stands (less than ½ acre each) have been identified. Aspen has the highest presence of the warm dry types. Cottonwood is rare and was only sampled on the Madison, Henrys Lake, Gallatin, Absaroka, and Beartooth Mountains analysis area.

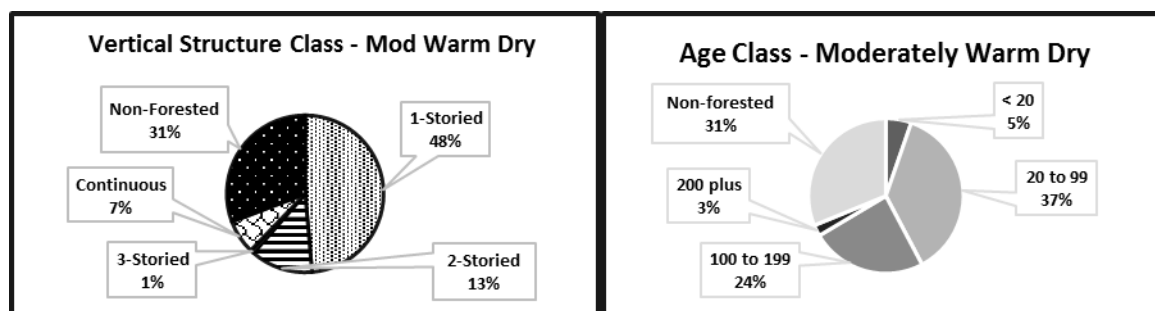
**Table 21. Presence of individual species of interest; proportion of the moderately warm dry habitat type group for Custer Gallatin National Forest, R1 summary database, forest inventory and analysis plots**

Paper birch	Green ash	Juniper	Whitebark pine	Limber pine	Cottonwood	Aspen
0.0%	1.6%	4.1%	1.5%	4.7%	0.4%	4.6%

## Structure

All five size classes are represented. Medium size class is most dominate, followed by the small class, and then the large class. Seedling/sapling and very large tree classes are less common. In contrast to the other hot and warm types this group has more representation across the size classes. Seedling/sapling size class is expected to increase as existing non-forested fire areas begin to reestablish with trees. Thirty four percent of the group has forested density class less than 10 percent. This group is moister than the other warm types and is more productive, so one would expect denser conditions, especially when frequent fire activity has been interrupted (fire suppression). Moderate/high or high density class represents 43 percent of the plots and 23 percent have moderate or low density class. Single story structure dominates followed by 2-storied. Eight percent of these sites have 3 or more canopy layers.





**Figure 40. Size class, density class, vertical structure class, and age class in the moderately warm dry habitat type group, forest inventory and analysis data, R1 summary database**

Old growth is estimated at 5.5 percent, the highest of the hot and warm dry types. Majority of the age class is less than 100 years, 24 percent of the plots were classified in the 100 to 199 age class. The 200 plus year class is uncommon at 3 percent.

Similarly as in the montane and pine savanna units, medium snags are dominant. Large and very large snags are below the estimate for both the montane and pine savanna units.

**Table 22. Estimates of Snags per acre on the moderately warm dry habitat type group for Custer Gallatin National Forest, R1 summary database, forest inventory and analysis plots**

Medium	Large	Very Large
8.79	2.20	0.79

Large down wood averages 4.2 tons per acre and is higher than the previous warm groups due to slightly more productive sites. Increases are expected as fire killed trees begin to fall in the recent fire areas.

### Function

On the montane unit, Douglas-fir is more dominate in this group. Thirty six percent has a moderate or high hazard rating to Douglas-fir beetle and thirty eight percent to western spruce budworm. Moderate or high hazard to mountain pine beetle in ponderosa pine and lodgepole pine is low. About a quarter of this group has a moderate or high combined beetle hazard.

**Table 23. Insect hazard ratings; proportion of the moderately warm dry habitat type group for Custer Gallatin National Forest, R1 summary database, forest inventory and analysis plots**

Insect	No Hazard	Low Hazard	Moderate Hazard	High Hazard
Douglas-fir beetle	49.1%	14.5%	24.9%	11.6%
Combined beetle <sup>1</sup>	66.9%	8.4%	12.1%	12.7%
Mountain pine beetle – lodgepole pine	85.2%	3.4%	8.7%	2.7%
Mountain pine beetle – ponderosa pine	87.6%	3.0%	5.6%	4.0%
Western spruce budworm	47.8%	14.0%	13.7%	24.4%

<sup>1</sup>Combined beetle includes mountain pine beetle (*Dendroctonus ponderosae*) and pine engraver beetles (*Ips* species). Hazard rating is for lodgepole pine, limber pine, whitebark pine, and ponderosa pine when present.

### **Connectivity-Pattern**

An analysis for stand replacing disturbance pattern (patch size) is currently being conducted using the SIMPPLLE model to determine a natural range of abundance and an average range of patch sizes. Considering the high frequency, low severity fire regime one would expect a small patch size. Analysis of existing patch size post disturbance using the Region 1 existing vegetation database that focused on the small size class (early successional forest) and transitional forest attributes was discussed earlier (see Forest Openings). Patch size metrics for this habitat type group include (Table 63 and Table 64 in appendix A):

- **Bridgers, Bangtails, Crazies**
  - ♦ **Transitional Forest** – 1,600 acres. On the dryer sites in this group, average patch size is 10 acres, largest 229 acres across 148 patches. The moist sites average 9 acres, largest 25 acres across 17 patches.
  - ♦ **Early Successional Forest** - There are 2,737 acres in this state. On the dryer sites in this group, average patch size 8 acres, largest 50 acres across 339 patches. The moist sites average 6 acres, largest 18 acres across 32 patches.
- **Madison, Henrys Lake, Gallatin, Absaroka, and Beartooth Mountains**
  - ♦ **Transitional Forest** – 77,542 acres. On the dryer sites, the average patch size is 35 acres largest 16,279 acres across 2,134 patches. The moist sites average 11 acres, with largest at 365 acres across 346 patches.
  - ♦ **Early Successional Forest** - There are 10,058 acres in this state. On the dryer sites, the average patch size is 8 acres largest 189 acres across 982 patches. The moist sites average 11 acres, with largest at 107 acres across 189 patches.
- **Pryors**
  - ♦ **Transitional Forest** – 2,845 acres. On the dryer sites, the average patch size is 126 acres largest 2,292 acres across 20 patches. The moist sites average 17 acres, with largest at 65 acres across 19 patches.
  - ♦ **Early Successional Forest** - There are 278 acres in this state. On the dryer sites, the average patch size is 6 acres largest 24 acres across 32 patches. The moist sites in this group have an average patch size of 5 acres, with largest at 9 acres across 18 patches.

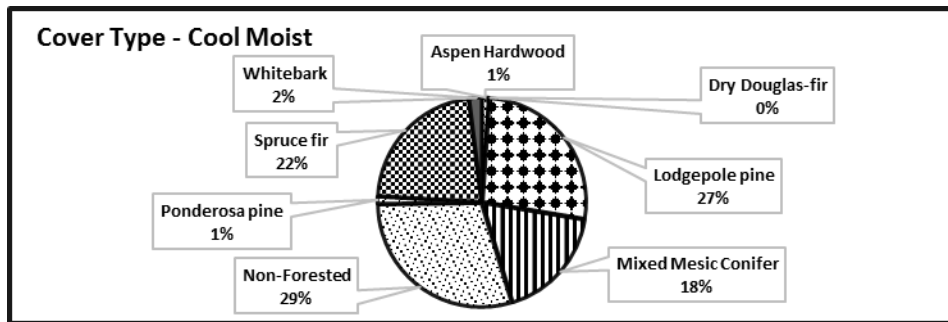
### ***Cool Moist Habitat Type Group***

Ninety four sub plots were sampled with this type representing about six percent of the analysis area. Moist subalpine fir and dry Engelmann spruce habitat types make up this group with a high diversity of species that may include Douglas-fir, Engelmann spruce, lodgepole pine, and subalpine fir. Lodgepole pine may dominate these sites after stand replacement disturbance.

### **Composition**

Lodgepole pine, spruce fir and mixed mesic conifer cover types make up 67 percent of the group. Whitebark pine, aspen hardwood, and ponderosa pine cover types are represented in low amounts. Ponderosa pine cover type would be expected in low elevation, dryer areas, whitebark pine cover type in the higher elevations, and aspen in moist areas and recent disturbance areas that have reduced the conifer component. Over one quarter of this type is dominated by non-forest conditions likely due to the recent fire disturbances.





**Figure 41. R1 cover type by proportion of habitat type group for Custer Gallatin National Forest, R1 summary database, forest inventory and analysis plots**

Five of the seven species of interest are present in the cool moist habitat type group. Whitebark pine in the higher elevations and limber pine in the lower to mid elevations have the highest presence. Even though the whitebark pine cover type is rare in this group it is individually present on 6 percent of the area. Aspen and paper birch presence is low and is dependent on disturbances that promote open conditions that reduces competition from more shade tolerant conifer species. This is the only group that has presence of paper birch sampled by forest inventory and analysis plots. Juniper is less common than in the warm dry types.

**Table 24. Presence of individual species of interest; proportion of the cool moist habitat type group for Custer Gallatin National Forest, R1 Summary Database, FIA plots**

Paper birch	Green ash	Juniper	Whitebark pine	Limber pine	Cottonwood	Aspen
1.1%	0.0%	2.2%	6.1%	5.8%	0.0%	3.3%

### Structure

Seedling/sapling class makes up 17 percent and the non-forest 29 percent indicative of past and recent disturbances. Medium and small tree classes are most abundant. Large tree class is less common and very large rare. Moderate/high or high density class makes up 53 percent and low or moderate 12 percent of the cool moist habitat type group. This group is dominated by single story structure, with 2-storied and continuous structure less dominant and nearly equally represented. Single story likely dominates in the lodgepole pine types and continuous story in the spruce fir and mixed mesic conifer cover types in the latter stages of succession.

Estimated old growth for this habitat type group is 10.9 percent; which is below the estimated old growth for the montane unit. The dominant age class is between 20 and 99 and 13 percent is less than 20. No plots were classified as 200 years or greater class. Again medium snags prevail and large snags are below the montane unit average. Very large snags are slightly above the montane unit average.

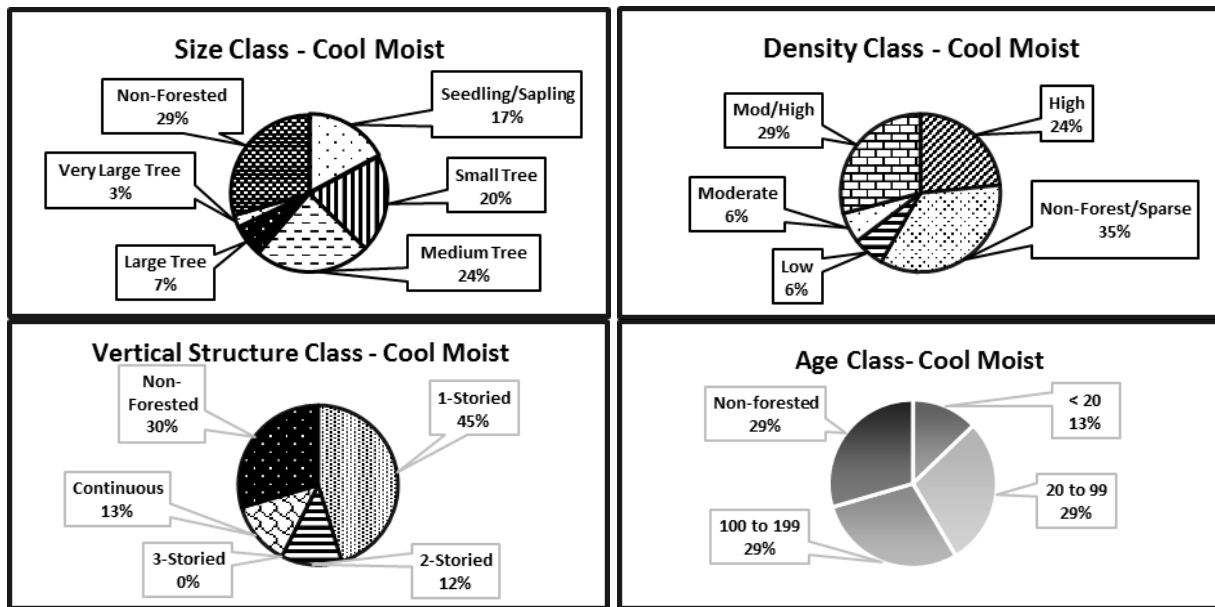


Figure 42. Size class, density class, vertical structure class, and age class in the cool moist habitat type group, forest inventory and analysis data, R1 summary database

Table 25. Estimates of snags per acre on the cool moist habitat type group for Custer Gallatin National Forest, R1 summary database, forest inventory and analysis plots

Medium	Large	Very Large
8.05	2.53	1.42

Large down woody debris is estimated at 13.9 tons per acre, the highest of all habitat type groups. Higher tons in moist sites would be expected in comparison to levels in dry sites as decomposition is slower.

### Function

Ponderosa pine cover type is rare in this group and reflective in the no hazard rating. Twenty seven percent of the dominant occurring lodgepole pine has been rated moderate or high hazard to mountain pine beetle. Moderate or high combined beetle hazard occurs on 29 percent of the area that has a dominant host. Where Douglas-fir is dominant, large, and high density 23 percent has a moderate or high hazard to Douglas-fir beetle. About 46 percent of the Douglas-fir dominant sites have a moderate or high hazard to western spruce budworm.

Table 26. Insect hazard ratings; proportion of the cool moist habitat type group for Custer Gallatin National Forest, R1 summary database, forest inventory and analysis plots

Insect	No Hazard	Low Hazard	Moderate Hazard	High Hazard
Douglas-fir beetle	63.0%	13.6%	12.3%	11.0%
Combined beetle <sup>1</sup>	51.8%	19.5%	18.0%	10.7%
Mountain pine beetle – lodgepole pine	59.6%	13.0%	19.8%	7.6%
Mountain pine beetle – ponderosa pine	100.0%	0.0%	0.0%	0.0%
Western spruce budworm	37.8%	16.7%	17.0%	28.6%

<sup>1</sup>Combined beetle includes mountain pine beetle (*Dendroctonus ponderosae*) and pine engraver beetles (*Ips* species). Hazard rating is for lodgepole pine, limber pine, whitebark pine, and ponderosa pine when present.

### **Connectivity-Pattern**

An analysis for stand replacing disturbance pattern (patch size) is currently being conducted using the SIMPPLLE model to determine a natural range of abundance and an average range of patch sizes. Considering the low frequency fire regime, one would expect a larger patch size under natural processes than those in the dryer types. Analysis of existing patch size post disturbance using the Region 1 existing vegetation database that focused on the small size class (early successional forest) and transitional forest attributes was discussed earlier (see Forest Openings). Patch size metrics for this habitat type group include (Table 63 and Table 64 in Appendix A):

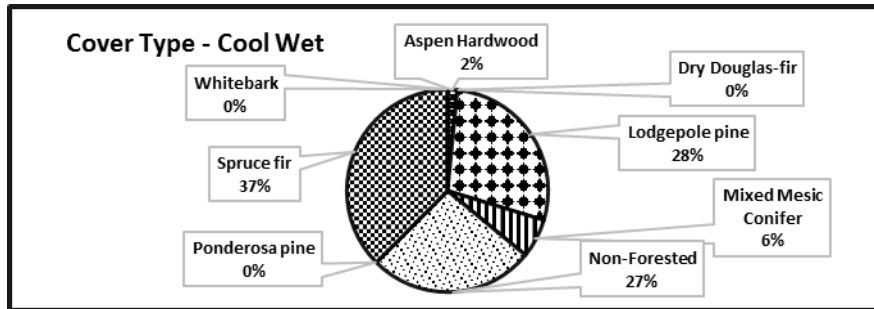
- Bridgers, Bangtails, Crazies
  - ♦ Transitional Forest – 105 acres. On the spruce potential vegetation sites in this group, average patch size is 8 acres, largest 13 acres across 6 patches. The subalpine fir potential vegetation sites average size is 10 acres, largest 29 acres across 6 patches.
  - ♦ Early Successional Forest - There are 167 acres in this state. On the spruce potential vegetation sites in this group average patch size 4 acres, largest 7 acres across 4 patches. The subalpine fir potential vegetation sites average 8 acres, largest 31 acres across 19 patches.
- Madison, Henrys Lake, Gallatin, Absaroka, and Beartooth Mountains
  - ♦ Transitional Forest – 13,244 acres. On the spruce potential vegetation sites in this group, average patch size is 13 acres, largest 144 acres across 273 patches. The subalpine fir potential vegetation sites average size is 22 acres, largest 3,246 acres across 449 patches.
  - ♦ Early Successional Forest - There are 5,909 acres in this state. On the spruce potential vegetation sites in this group, average patch size is 9 acres, largest 77 acres across 183 patches. The subalpine fir potential vegetation sites average 11 acres, largest 123 acres across 385 patches.
- Pryors
  - ♦ Transitional Forest – 78 acres. Average patch size is 13 acres, largest 23 acres across 6 patches.

### ***Cool Wet Habitat Type Group***

The cool wet habitat type group has 69 sub plots all on the montane unit (4.77 percent of the area). These are moist subalpine fir and Engelmann spruce habitat types, generally associated with riparian areas or wetlands where fire intervals are long. These are typically dominated by the climax species with Douglas-fir, lodgepole pine, and aspen/hardwoods presence. Natural fire interval is usually long.

### **Composition**

Not surprising spruce fir cover type is the dominant cover type as this habitat type is generally dominated by subalpine fir and Engelmann spruce. Lodgepole pine cover type is common and mixed mesic conifer cover type is less common. Non-forested sites make up about ¼ of the area and are likely dominated by riparian shrubs and forbs.



**Figure 43. R1 cover type by proportion of habitat type group for Custer Gallatin National Forest, R1 summary database, forest inventory and analysis plots**

Aspen and whitebark pine are the only species of interest present in this habitat type group. Whitebark pine is present in this type but does not have a competitive advantage to dominate.

**Table 27. Presence of individual species of interest; proportion of the cool wet habitat type group for Custer Gallatin National Forest, R1 summary database, forest inventory and analysis plots**

Paper birch	Green ash	Juniper	Whitebark pine	Limber pine	Cottonwood	Aspen
0.0%	0.0%	0.0%	7.8%	0.0%	0.0%	3.1%

### Structure

Medium size tree class dominates and the small tree and large tree classes are common. Seedling/sapling and very large tree classes are less common. This habitat type group, along with the cool to moderately dry group, has the highest representation of the very large tree class. Moderate/high or high density class is most common. Moderate or low density class is less common at 21 percent. Single story structure is most dominant and likely in the lodgepole pine cover types that are in earlier successional stages. Two-storied and multi-storied conditions are common and likely associated with the later successional stage in the lodgepole pine cover types and in the more shade tolerant species in the spruce fir cover types.

Old growth is estimated at 20.3 percent in the cool wet group, slightly above the 20.1 percent estimate for the montane unit. Sixty seven percent is in an age class of 20 to 199, 6 percent in the less than 20 class with no plots classified in the 200 plus class. Age class diversity is low with the majority in the 100 to 199 class. No plots were classified in the 200 plus class. Large snags and very large snags are above the average per acre for the montane unit.

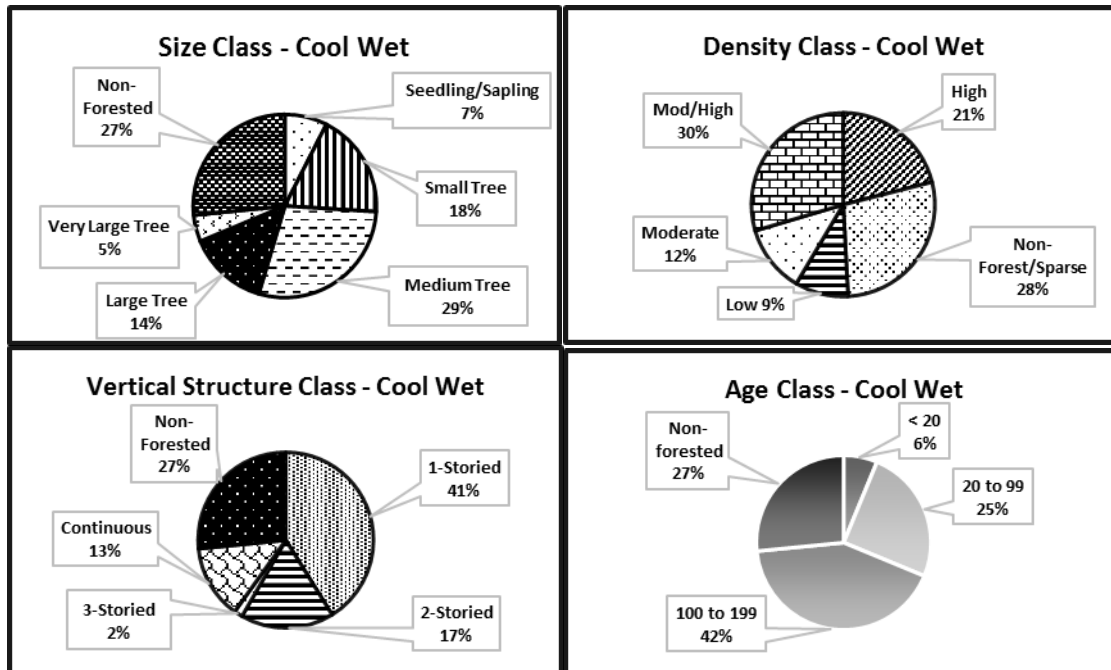


Figure 44. Size class, density class, vertical structure class, and age class in the cool wet habitat type group, forest inventory and analysis data, R1 summary database

Table 28. Estimates of Snags per acre on the cool wet habitat type group for Custer Gallatin National Forest, R1 summary database, forest inventory and analysis plots

Medium	Large	Very Large
14.78	4.13	3.76

Large downed woody debris averages 10.3 tons per acre and like other moist habitat types is higher than the dry types.

### Function

Ponderosa pine was not sampled in this habitat type group, therefore no beetle hazard was assessed. Where lodgepole pine is present 30 percent has a moderate or high mountain pine beetle hazard. Douglas-fir is most present in the mixed mesic conifer cover type and has about 8 percent moderate or high hazard to Douglas-fir beetle. The combined beetle hazard for all the pine host species present have 36 percent rated as moderate or high. The highest insect hazard is from the western spruce budworm, with 54 percent in a moderate or high hazard. High hazard is predominately in the spruce/fir cover type that generally is multilayered. Moderate hazard and limited high hazard occurs in the mixed mesic conifer where Douglas-fir is more common.

**Table 29. Insect hazard ratings; proportion of the cool wet habitat type group for Custer Gallatin National Forest, R1 summary database, forest inventory and analysis plots**

Insect	No Hazard	Low Hazard	Moderate Hazard	High Hazard
Douglas-fir beetle	83.9%	8.3%	4.7%	3.1%
Combined beetle <sup>1</sup>	54.7%	9.4%	17.5%	18.4%
Mountain pine beetle – lodgepole pine	62.5%	7.5%	21.7%	8.37%
Mountain pine beetle – ponderosa pine	100.0%	0.0%	0.0%	0.0%
Western spruce budworm	37.8%	7.8%	21.6%	32.8%

<sup>1</sup>Combined beetle includes mountain pine beetle (*Dendroctonus ponderosae*) and pine engraver beetles (*Ips* species). Hazard rating is for lodgepole pine, limber pine, whitebark pine, and ponderosa pine when present.

### Connectivity-Pattern

An analysis for stand replacing disturbance pattern (patch size) is currently being conducted using the SIMPPLLE model to determine a natural range of abundance and an average range of patch sizes. Considering the long fire return interval and in the generally wet riparian setting one would expect a small patch size. Analysis of existing patch size post disturbance using the Region 1 existing vegetation database that focused on the small size class (early successional forest) and transitional forest attributes was discussed earlier (see Forest Openings). Patch size metrics for this habitat type group include (Table 63 and Table 64 in Appendix A):

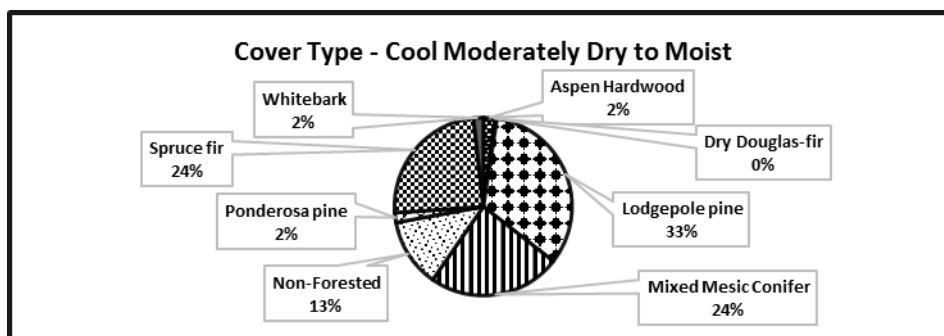
- Bridgers, Bangtails, Crazies
  - ♦ Transitional Forest – 104 acres. Average patch size is 5 acres, largest 14 acres across 21 patches.
  - ♦ Early Successional Forest - There are 584 acres in this state. Average patch size 6 acres, largest 18 acres across 96 patches.
- Madison, Henrys Lake, Gallatin, Absaroka, and Beartooth Mountains
  - ♦ Transitional Forest – 7,458 acres. Average patch size is 13 acres, largest 568 acres across 590 patches.
  - ♦ Early Successional Forest - There are 3,605 acres in this state. Average patch size 8 acres, largest 59 acres across 452 patches.

### Cool Moderately Dry to Moist Habitat Type Group

This habitat type group is the second most common on the montane unit. There are 280 subplots that represent the drier subalpine fir and Engelmann spruce habitat types on 25.5 percent of the area. The highest representation for lodgepole pine cover occurs in this group. Under a natural infrequent fire regime, stand replacement events occurred in lodgepole dominated sites. Mixed severity fires were also common to create mosaics of lodgepole pine, Douglas-fir, and whitebark pine. Whitebark pine is present in this group but does not have a competitive advantage to persist as a dominant.

### Composition

Lodgepole pine cover type makes up 33 percent of the group. Spruce fir and mixed mesic conifer cover types each make up 24 percent. Aspen hardwood, ponderosa pine, and whitebark pine cover types are less common each representing about 2 percent of the area. Currently 13 percent of the cool moderately dry to moist habitat type group is in non-forested conditions.



**Figure 45. R1 cover type by proportion of habitat type group for Custer Gallatin National Forest, R1 summary database, forest inventory and analysis plots**

Whitebark pine and limber pine have the highest presence of the individual species of interest. Although not common cover types these two species can occur together. Juniper and cottonwood presence are rare. Aspen dominance occurs in small areas generally in the moist areas that have recently been disturbed and void of conifer overstory. Aspen, whitebark pine, and limber pine all have the potential to expand with management or by natural disturbances.

**Table 30. Presence of individual species of interest; proportion of the cool moderately dry to moist habitat type group for Custer Gallatin National Forest, R1 summary database, forest inventory and analysis plots.**

Paper birch	Green ash	Juniper	Whitebark pine	Limber pine	Cottonwood	Aspen
0.0%	0.0%	0.4%	9.6%	9.9%	0.7%	2.1%

### Structure

The cool moderately dry to moist habitat type group supports a good distribution of seedling/sapling, small tree, medium, and large tree classes. The very large class is less common at 5 percent. Sixty four percent, the highest of all the habitat type groups is represented in moderate/high or high density class. Low or moderate density makes up 19 percent. Vertical structure class tends to be single storied, likely in the lodgepole pine cover types that are in earlier successional stages. Continuous canopy layers represents 23 percent of the area and more likely in the spruce fir cover types. Two-story structure makes up 17 percent.

Old growth is estimated at 25.5 percent of the cool moderately dry to moist habitat type; second highest by proportion of area. And above the average for the montane unit. The group has a fairly even distribution of the 20 to 199 age classes and nearly equal of the youngest and oldest age classes. This habitat type group has the highest amount of area that is classified in the 200 plus age class at 8 percent. Medium size snags are most dominant with large estimated at 4.63 per acre and very large at less than 1 per acre. Large snags are above and very large are below the average for the montane unit.

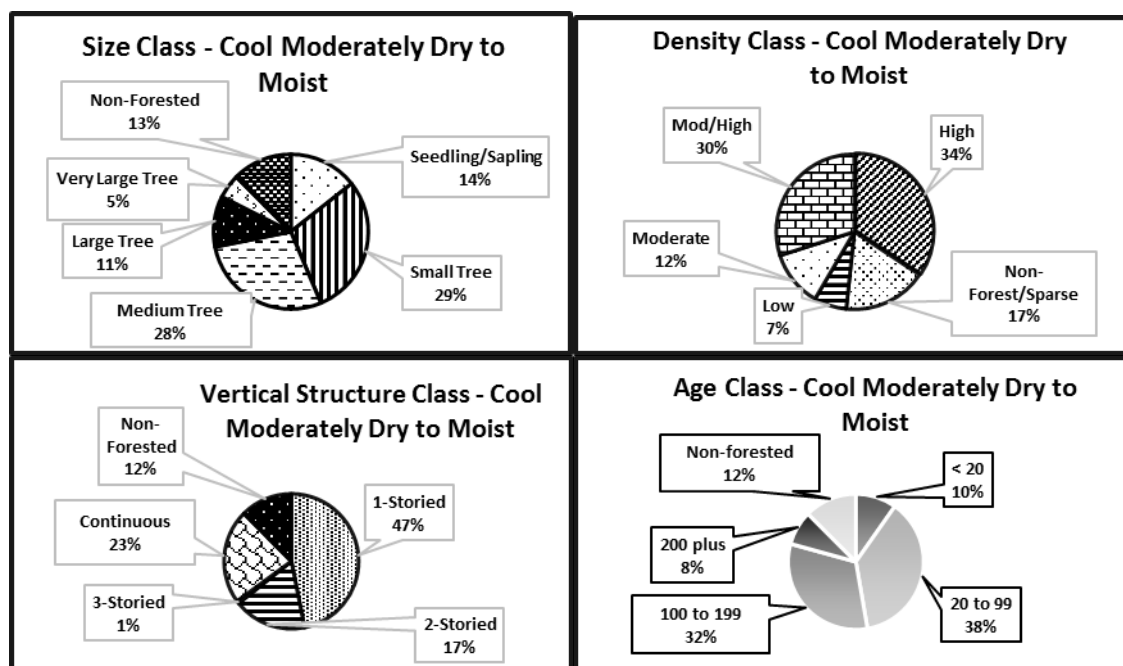


Figure 46. Size class, density class, vertical structure class, and age class in the cool moderately dry to moist habitat type group, forest inventory and analysis data, R1 summary database

Table 31. Estimates of snags per acre on the cool moderately dry to moist habitat type group for Custer Gallatin National Forest, R1 summary database, forest inventory and analysis plots

Medium	Large	Very Large
17.86	4.63	0.73

Like other cool, moist habitat type groups downed large woody debris tends to be higher when compared to the warmer dryer types. Downed woody debris greater than or equal to 3 inches is estimated at 11.1 tons per acre.

## Function

Sixty three percent of the habitat type group has been rated with a moderate or high hazard to western spruce budworm. A quarter of the area has been rated moderate or high hazard to Douglas-fir beetle. Low to moderate hazards for western spruce beetle tend to occur in the lodgepole pine cover types where the amount of host species tend to be lower, while in the mixed mesic conifer and spruce fir cover types where the host species tend to be more dominant the majority of moderate and high hazards occur. Ponderosa pine is not in sufficient quantity and therefore has no hazard assessed for mountain pine beetle. Over half of the lodgepole pine has been assessed a hazard to mountain pine beetle with 34 percent having a moderate or high hazard. Nearly half of the pine species where they occur have been assessed a moderate or high hazard for mountain pine beetle and/or the pine engraver beetle.



**Table 32. Insect hazard ratings; proportion of the cool moderately dry to moist habitat type group for Custer Gallatin, R1 Summary Database, FIA plots**

Insect	No Hazard	Low Hazard	Moderate Hazard	High Hazard
Douglas-fir beetle	62.0%	13.4%	15.7%	8.9%
Combined beetle <sup>1</sup>	35.4%	17.1%	26.3%	21.2%
Mountain pine beetle – lodgepole pine	47.6%	18.7%	27.3%	6.4%
Mountain pine beetle – ponderosa pine	100.0%	0.0%	0.0%	0.0%
Western spruce budworm	30.1%	6.4%	28.7%	34.8%

<sup>1</sup>Combined beetle includes mountain pine beetle (*Dendroctonus ponderosae*) and pine engraver beetles (*Ips* species). Hazard rating is for lodgepole pine, limber pine, whitebark pine, and ponderosa pine when present.

### Connectivity-Pattern

An analysis for stand replacing disturbance pattern (patch size) is currently being conducted using the SIMPPLLE model to determine a natural range of abundance and an average range of patch sizes. Under natural fire regimes infrequent stand replacement fires tended to occur on sites dominated by lodgepole pine that likely created a large patch size. Mixed severity fires were also common that could promote a mosaic of smaller and moderate patch sizes. Analysis of existing patch size post disturbance using the Region 1 existing vegetation database that focused on the small size class (early successional forest) and transitional forest attributes was discussed earlier (see Forest Openings). Patch size metrics for this habitat type group include (Table 63 and Table 64 in Appendix A):

- Bridgers, Bangtails, Crazies
  - ◆ Transitional Forest – 1,498 acres. Average patch size is 15 acres, largest 378 acres across 103 patches.
  - ◆ Early Successional Forest - There are 3,729 acres in this state. On the lodgepole pine potential vegetation sites in this group, average patch size is 8 acres, largest 88 acres across 126 patches. The subalpine fir potential vegetation sites average 10 acres, largest 64 acres across 281 patches.
- Madison, Henrys Lake, Gallatin, Absaroka, and Beartooth Mountains
  - ◆ Transitional Forest – 53,225 acres. On the lodgepole pine potential vegetation sites in this group, average patch size is 77 acres, largest 2,600 acres across 40 patches. The subalpine fir potential vegetation sites average size is 25 acres, largest 3,419 acres across 2007 patches.
  - ◆ Early Successional Forest - There are 35,187 acres in this state. On the lodgepole pine potential vegetation sites in this group, average patch size is 13 acres, largest 277 acres across 680 patches. The subalpine fir potential vegetation sites average 16 acres, largest 893 acres across 1,695 patches.
- Pryors
  - ◆ Early Successional Forest – 83 acres. Average patch size is 6 acres, largest 21 acres across 14 patches.

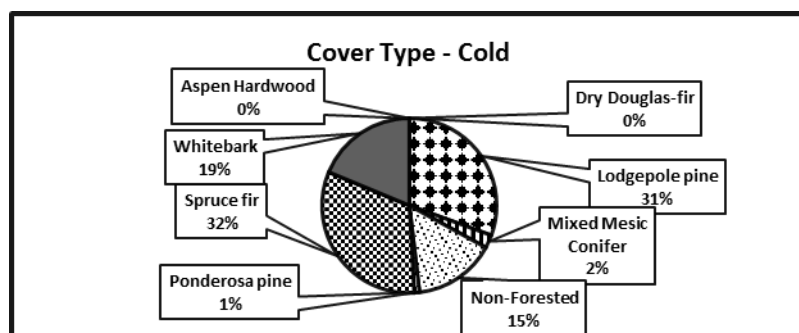
### Cold Habitat Type Group

The cold habitat type group is the most common on the montane unit and represents about 29 percent of the area. There are 414 sub plots classified to this habitat type group. High elevation subalpine

climax types dominate with lodgepole pine, subalpine fir, Engelmann spruce, and whitebark pine all present. Under a natural, long-interval fire regime, whitebark pine could be favored.

### Composition

Spruce fir, lodgepole pine, and whitebark pine cover types dominate on 82 percent of the area. Whitebark pine has the second highest representation across the habitat type groups at 19 percent of the area. Douglas-fir and ponderosa pine cover types are rare. Where the ponderosa pine cover type occur, these sites are dominated by limber pine.



**Figure 47. R1 cover type by proportion of habitat type group for Custer Gallatin National Forest, R1 summary database, forest inventory and analysis plots**

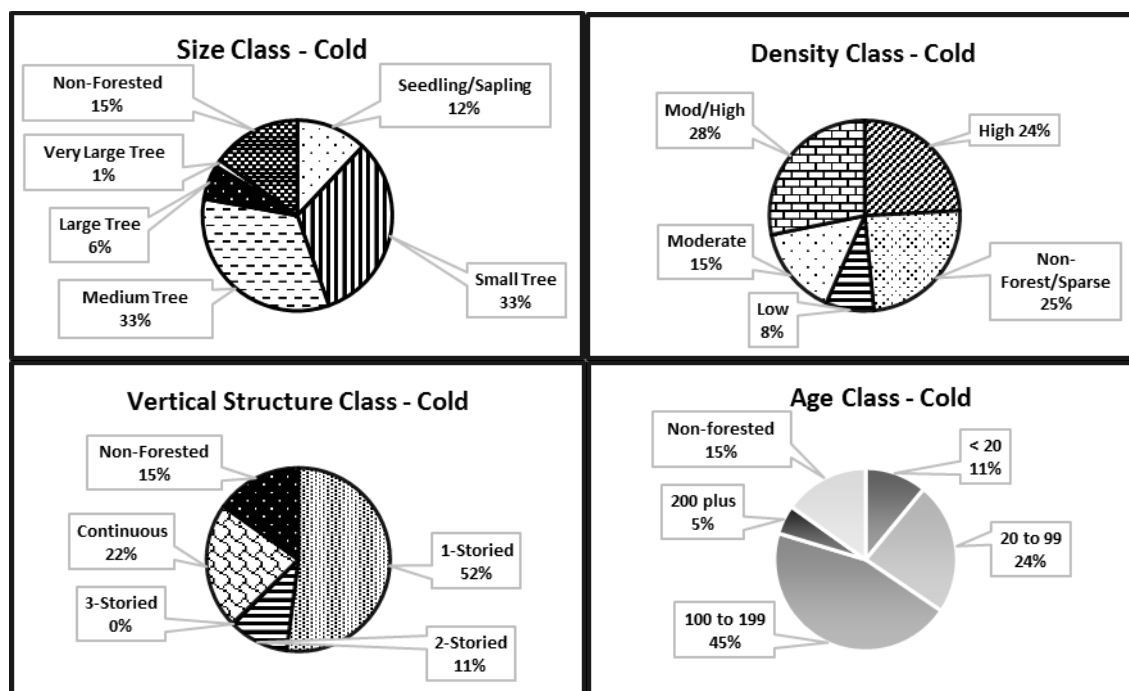
Whitebark pine, limber pine, and aspen are the only species of interest that occur in these high elevation sites. Aspen is rare on these higher elevation sites and only occurred on 1 sub plot in a lodgepole pine cover type. Limber pine presence is most common in the lodgepole pine cover types. Whitebark pine presence is common in the lodgepole pine and spruce fir cover types.

**Table 33. Presence of individual species of interest; proportion of the cold habitat type group for Custer Gallatin National Forest, R1 summary database, forest inventory and analysis plots**

Paper birch	Green ash	Juniper	Whitebark pine	Limber pine	Cottonwood	Aspen
0.0%	0.0%	0.0%	37.9%	7.5%	0.0%	0.2%

### Structure

Low diversity across all the structure attributes occur with over 50 percent of each in 1 or 2 classes. Sixty six percent of the area is in the small and medium size class, seedling/sapling at 14 percent and large size class less common at 6 percent. Very large size class is rare at 1 percent. Single-story structure is dominant on 52 percent and continuous less common on 22 percent of the area. Two-story structure is least common on 11 percent. Ten percent of the area has trees present but less than 10 percent cover. Current non-forest cover is low at 15 percent and likely due to the recent fire disturbances.



**Figure 48. Size class, density class, vertical structure class, and age class in the cold habitat type group, forest inventory and analysis data, R1 summary database**

It is estimated that about 34 percent of this group is currently old growth; the highest of all habitat type groups and above the estimated amount for the montane unit. Limited disturbance and longer lived species such as whitebark pine contribute to the amount of old growth. Fifty percent of the area occurs in the classes greater than 100 years, with 5 percent in the 200 plus class. Thirty five percent is less than 100 years, while the less than 20 age class comprises 11 percent of the area. Medium snags like all habitat type groups are dominate. Large snags at 5.87 per acre and very large at 1.64 per acre both exceed the average for those size classes for the montane unit. Recent fires and mountain pine beetle activity likely has influenced the existing snag conditions.

**Table 34. Estimates of Snags per acre on the cold habitat type group for Custer Gallatin National Forest, R1 summary database, forest inventory and analysis plots**

Medium	Large	Very Large
22.81	5.87	1.64

Downed large woody debris at 11 tons per acre is above the estimated average for the montane unit which is at 8.1 tons per acre.

### Function

Presence of Douglas-fir is less common in these high elevation sites, and therefore results in a low hazard for Douglas-fir beetle. Ponderosa pine is absent. With the higher presence of other species susceptible to the western spruce budworm, 58 percent has been rated with a moderate or high hazard. The dominant higher density classes and common two or more vertical canopy structures contributes to these hazard ratings. Where lodgepole pine is present, 32 percent has been rated with a moderate or high hazard to mountain pine beetle. Seventy one percent of pine species when present are susceptible

to mountain pine beetle and the engraver beetle have been assessed with a hazard; 56 percent with a moderate or high hazard.

**Table 35. Insect hazard ratings; proportion of the cold habitat type group for Custer Gallatin National Forest, R1 summary database, forest inventory and analysis plots**

Insect	No Hazard	Low Hazard	Moderate Hazard	High Hazard
Douglas-fir beetle	93.7%	2.8%	3.5%	0.0%
Combined beetle <sup>1</sup>	28.9%	14.6%	20.4%	36.1%
Mountain pine beetle – lodgepole pine	57.1%	11.3%	23.6%	8.0%
Mountain pine beetle – ponderosa pine	100.0%	0.0%	0.0%	0.0%
Western spruce budworm	26.5%	15.9%	36.6%	21.1%

<sup>1</sup>Combined beetle includes mountain pine beetle (*Dendroctonus ponderosae*) and pine engraver beetles (*Ips* species). Hazard rating is for lodgepole pine, limber pine, whitebark pine, and ponderosa pine when present.

### Connectivity-Pattern

An analysis for stand replacing disturbance pattern (patch size) is currently being conducted using the SIMPPLLE model to determine a natural range of abundance and an average range of patch sizes. Under natural fire regimes most fires in this group were low severity, although high severity occurred at long intervals, likely resulting in various patch sizes. Analysis of existing patch size post disturbance using the Region 1 existing vegetation database that focused on the small size class (early successional forest) and transitional forest attributes was discussed earlier (see Forest Openings). Patch size metrics for this habitat type group include (Table 63 and Table 64 in Appendix A):

- Bridgers, Bangtails, Crazies
  - ♦ Transitional Forest – 88 acres. Average patch size is 7 acres, largest 17 acres across 12 patches.
  - ♦ Early Successional Forest - There are 67 acres in this state. Average patch size 6 acres, largest 14 acres across 12 patches.
- Madison, Henrys Lake, Gallatin, Absaroka, and Beartooth Mountains
  - ♦ Transitional Forest – 15,300 acres. Average patch size is 21 acres, largest 1,399 acres across 726 patches.
  - ♦ Early Successional Forest - There are 3,870 acres in this state. Average patch size 11 acres, largest 134 acres across 340 patches.

### Timberline Type Group

Timberline habitat type makes up about 8 percent of the montane unit. There are 118 subplots representing this type. Whitebark pine is the climax type, with subalpine fir and Engelmann spruce both common. Douglas-fir and lodgepole pine are present but rare.

### Composition

Not surprising whitebark pine cover type is most dominate on this group at 38 percent of the area. Subalpine fir cover type is common on 26 percent, while mixed mesic conifer type at 3 percent and lodgepole pine cover type at 1 percent of the area are rare. Currently 32 percent is dominated by non-forest vegetation cover type.

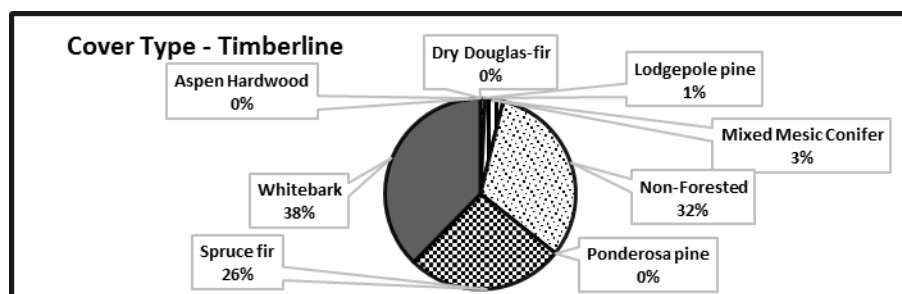


Figure 49. R1 cover type by proportion of habitat type group for Custer Gallatin National Forest, R1 summary database, forest inventory and analysis plots

On these cold, high-elevation timberline sites, whitebark pine is the only individual species of interest present on 57 percent of the currently forested plots. All other species are above their cold tolerance for survival.

Table 36. Presence of individual species of interest; proportion of the timberline habitat type group for Custer Gallatin National Forest, R1 summary database, forest inventory and analysis plots.

Paper birch	Green ash	Juniper	Whitebark pine	Limber pine	Cottonwood	Aspen
0.0%	0.0%	0.0%	57.3%	0.0%	0.0%	0.0%

### Structure

Small tree class is dominant on 31 percent of the timberline habitat type group. Medium tree, large tree, and seedling/sapling classes are about equal making up 36 percent. The very large tree class is rare. Density class is fairly evenly distributed, with moderate/high and high classes slightly more represented than the low and moderate classes. Vertical structure is dominated by single structure, while continuous and 2-storied are less common.

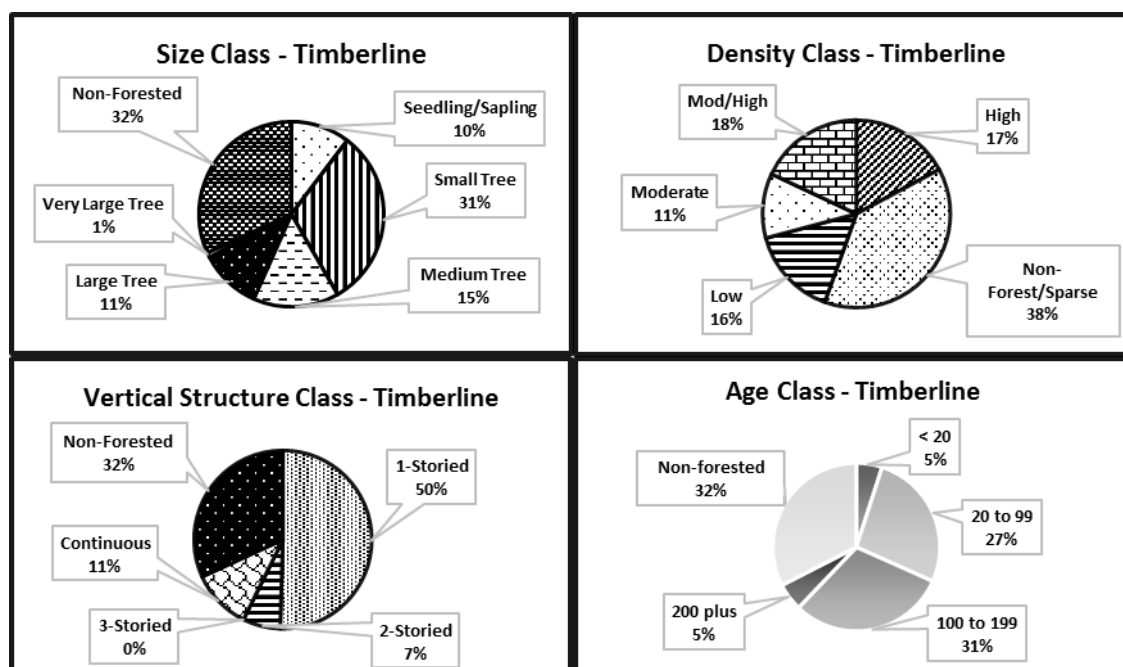


Figure 50. Size class, density class, vertical structure class, and age class in the timberline habitat type group, forest inventory and analysis data, R1 summary database

The timberline habitat type group has an estimated 21.7 percent old growth, slightly above the average for the montane unit. The 20 to 99 age classes make up nearly equal amounts on 58 percent of the area. The youngest (less than 20) and oldest class (200 plus) each make up about 5 percent. Like the cold habitat type all size classes of snags are higher than the average for the montane unit. Contributing factors for this are longer lived species such as whitebark pine, long fire interval and current blister rust and mountain pine beetle mortality in the whitebark pine.

**Table 37. Estimates of snags per acre in the timberline habitat type group for Custer Gallatin National Forest, R1 summary database, forest inventory and analysis plots**

Medium	Large	Very Large
12.95	4.01	1.51

Estimated down woody debris 3 inches and larger in diameter is relatively low in comparison to other cool to cold habitat type groups at 3.3 tons per acre.

### Function

Lodgepole pine, Douglas-fir and ponderosa pine are uncommon or non-existent in this group and so have very low hazards to the pest of interest. Spruce and alpine fire which are common have about 37% moderate and high hazard to western spruce budworm. Whitebark pine and the limited lodgepole pine have 44% at a moderate or high hazard (combined beetle).

**Table 38. Insect hazard ratings; proportion of the timberline habitat type group for Custer Gallatin National Forest, R1 summary database, forest inventory and analysis plots**

Insect	No Hazard	Low Hazard	Moderate Hazard	High Hazard
Douglas-fir beetle	95.0%	2.3%	2.0%	0.7%
Combined beetle <sup>1</sup>	41.8%	14.6%	17.4%	26.2%
Mountain pine beetle – lodgepole pine	96.7%	2.5%	0.8%	0.0%
Mountain pine beetle – ponderosa pine	100.0%	0.0%	0.0%	0.0%
Western spruce budworm	47.3%	16.0%	26.5%	10.2%

<sup>1</sup>Combined beetle includes mountain pine beetle (*Dendroctonus ponderosae*) and pine engraver beetles (*Ips* species). Hazard rating is for lodgepole pine, limber pine, whitebark pine, and ponderosa pine when present.

### Connectivity-Pattern

An analysis for stand replacing disturbance pattern (patch size) is currently being conducted using the SIMPPLLE model to determine a natural range of abundance and an average range of patch sizes. The natural fire regime was variable and included low and mixed severity likely resulting in a variable patch size. Analysis of existing patch size post disturbance using the Region 1 existing vegetation database that focused on the small size class (early successional forest) and transitional forest attributes was discussed earlier (see Forest Openings). Patch size metrics for this habitat type group include (Table 63 and Table 64 in Appendix A):

- Bridgers, Bangtails, Crazies
  - ♦ Transitional Forest – 112 acres. Average patch size is 11 acres, largest 52 acres across 10 patches.

- ♦ Early Successional Forest - There are 41 acres in this state. Average patch size 12 acres, largest 3 acres across 13 patches.
- Madison, Henrys Lake, Gallatin, Absaroka, and Beartooth Mountains
  - ♦ Transitional Forest – 8,751 acres. Average patch size is 21 acres, largest 544 acres across 417 patches.
  - ♦ Early Successional Forest - There are 5,801 acres in this state. Average patch size 5 acres, largest 109 acres across 1,109 patches.

## Trends

Trends for cover type, structure, function, and connectivity have been discussed in prior sections but not for each potential vegetation group separately. Trends for each habitat type group may vary but are similarly shaped by natural disturbances and processes, climate, fire suppression, and other human influences. This section discusses general historic conditions and future trends with potential climate change.

## Historic Conditions

Low elevation, dry forests in Region 1, such as those found on the hot dry, warm dry, and moderately warm dry habitat type groups, have experienced perhaps the greatest magnitude of change in composition, structure and function because of fire suppression, forest management, and climate change (Hessburg et al. 2005). These dry forest types account for about 18 percent of the montane unit and are the only type on the pine savanna unit.

Prior to Euro-Americans settlement, dry forest types were burned by frequent low or mixed severity fires (Hessburg et al. 2005, Brown and Sieg 1996, Mutch 1994, Graham et al. 2004, and Sneed 2005). These mostly surface fires maintained low and variable tree densities, light and patchy ground fuels, simplified forest structure, and favored a patchy cover of associated fire-tolerant shrubs and herbs (Hessburg et al. 2005). Low severity fires maintained fire-resilient structures by elevating tree crown bases and scorching or consuming many seedlings, saplings, and pole-sized trees. Such fires cycled nutrients from branches and foliage to the soil, where they could be used by other plants, and promoted the growth and development of low and patchy understory shrub and herb vegetation. Finally, surface fires reduced the long-term threat of running crown fires by reducing the fuel bed and metering out individual tree and group torching, and they reduced competition for site resources (nutrients, light, and water) among surviving trees, shrubs and herbs. Rarely, dry forest landscapes were affected by more severe climate-driven events (ibid).

Dry forests no longer appear or function as they once did. Large landscapes are becoming more homogeneous in their compositions and structure, and many of these landscapes are set up for severe, large fire and insect disturbance events (ibid). Hessburg et al (2005) noted the following and effects on dry forest types:

**Table 39. Changes and effect in dry forest landscapes**

Change	Effect
Reduced grassland and shrubland area in forest potential vegetation settings and expanded forest area.	Increased homogeneity of the landscape vegetation and fuels mosaic.
Reduced old and new forest area.	Increased homogeneity of the landscape vegetation and fuels mosaic, reduced spatial isolation of areas prone to high-severity fires.
Loss of grass and shrub understories.*	Reduced likelihood of low-severity fires with increasing flame length, fire-line intensity, rate of spread, increased fuel ladders and likelihood of crown fire.
Increased tree canopy cover, and canopy layers.*	Increased fuel ladders, potential flame lengths, fire-line intensity, rate of spread, and likelihood of crown fires.
Increased young multi-story forest area.*	Increased landscape homogeneity, reduced fire tolerance, increased fuel ladders, potential flame lengths, fire-line intensity, rate of spread, and likelihood of crown fires.

\*Indicates a strong correlation with current severe fire behavior.

There is little evidence that current patterns in dry forest today are sustainable and this has important ecological consequences (ibid). Dry forest types on the Custer Gallatin National Forest are increasing in homogeneity in their composition and structure, and the landscape is set up for severe, large fire and/or potential insect disturbance events. To date, wildland fires alone have not created ecological outcomes that are desired by society or that are consistent with natural ecosystem functioning.

Lodgepole pine cover type is common in the cool moist, cool wet, cool, moderately dry to moist, and the cold habitat type groups on the montane unit. The natural fire regime is a low frequency, high severity fire, however they have experienced shifts due to fire suppression and changes in climate. Most people think of lodgepole pine as even-aged forests that have regenerated from stand replacement events. But this vegetation type burned in both stand replacement crown and low to mixed severity surface type fires, creating variable age structures and pattern (Franklin and Lavin 1990, Hardy et al. 2000; Kashian 2005). Crown fires killed all species but gave colonization advantage to the serotinous lodgepole pine. Surface fires only scarred lodgepole but killed most of the understory (e.g. subalpine fir and spruce) thereby delaying succession (Brown 1975). However, Keane et al. (2002) reported the majority of stand-replacement fire in lodgepole pine was actually severe surface fires. And a fire history study on the Lewis and Clark National Forest found that mixed severity fires often occurred within 50 years of a previous fire, fueled by dense post-fire regeneration and snags (Barrett 1993). Fire exclusion has converted some forests from lodgepole pine to fir and spruce (Keane et al. 2002). In addition, some stand structures have gone from single age or diameter-class dominance (even aged) to multiple age and diameter classes (uneven aged) (ibid). At the landscape scale, fire suppression (particularly of small fires) has had the effect of decreasing acreage burned in normal fire seasons and reducing the natural variability in landscape patterns (ibid). As a result, the larger, contiguous blocks of uniform stands are subject to large beetle outbreaks and catastrophic fires when fire weather is extreme (USDA 1990; Barrett 1993; Keane et al. 2002).

Whitebark pine cover type is common in the cold habitat type group (19 percent) and the dominant cover type in the timberline (38 percent). Whitebark pine is a long-lived species and without fire the successional pathway is replacement by subalpine fir and spruce. Succession of subalpine fir and spruce into seral whitebark pine stands creates multilayered canopies with low crown base heights and high crown bulk densities, increasing the chance of stand-replacement fires (Murray and others 1995). The conversion of a mixed-severity fire regime to a stand-replacement regime is a consequence of fire



exclusion (Arno and others 1993; Loope and Gruell 1973). Fires in this new regime will tend to be larger and more intense (Keane et al. 2002). Effects of fire exclusion have been accelerated by the introduction of the white pine blister rust, which has devastated many whitebark pine stands in the Northern Rockies, resulting in landscapes with abnormally high coverages of subalpine fir types is another effect of fire exclusion (Keene et al. 2002).

## Future Conditions

Even though knowledge in climate change research is continually evolving and has some uncertainties, existing information indicates forests in the Northern Rockies are highly sensitive to projected climate change (Running 2010, Scott et al. 2013). Various models on climate change indicate similar climate change assumptions:

- Rising temperatures
- Changes in precipitation cycles resulting in
  - ◆ Less snow, more rain
  - ◆ Less water stored in snowpack
  - ◆ Earlier spring snowmelt and peak runoff
  - ◆ Lower stream flow in summer
  - ◆ Longer summer drought
  - ◆ Alter site water balances

Consequences of these changes could lead to: increased water stress to some species, favorable climate to sustain insect infestations, longer fire seasons with favorable burning conditions, and changes in growing season. Potential consequences from these shifting climate assumptions will likely cause plant communities to undergo shifts in species composition and/or changes in densities at landscape levels (Scott et al. 2013). Species range shifts are expected to be species specific rather than current communities of associated species (Shafer 2001, Rehfeldt et al. 2006, McKinney et al. 2007). Individual species that have narrow biophysical niches or poor dispersal ability will have less ability to adapt to climate changes. This may lead to potential for localized loss of biological diversity if environmental shifts outpace species migration rates (Aitken et al. 2008, Littell et al. 2009)

In 2013, Region 1 undertook an effort to look at how forests might respond to climate change and how the region might incorporate impacts into reforestation and revegetation efforts (Scott et al. 2013). Silviculturists across the region, with assistance from research scientists and the regional geneticist, identified the species and habitat conditions most vulnerable to a warmer and drier climate. The group synthesized their knowledge of species silvics and autecology with their understating of interactions of long term drought, insect, disease, fire disturbances and the complexity of soils and topography. Table 40 and

Table 41 summarize this effort of assumptions and potential trends of individual conifer species, general growing site habitats, and habitat type groups and how they may respond to climate change assumptions stated above. See Climate Change section for additional information on individual species. Table 40. Summarized assumptions/potential trends with climate change by growing site habitats and individual conifer species

General Forest Condition	Adaptive Strategy <sup>1</sup> and Assumptions/ Potential Trends with Climate Change
Dry habitats and lower tree line	Increased temperature could potentially inhibit tree establishment. Greater winter precipitation may result in moving the tree line downslope. Changes will be species dependent (Shafer et al. 2001, Rice et al. 2012).
Mesic habitats	Dry summers will be extended leading to decreases in water availability. Increased drought stress. Root pathogens could increase. These sites have considerable uncertainty and vulnerability due to the diversity of species and complexities of site conditions.
High elevation and tree line species	Climate change may alter snowpack/moisture regimes in the spring and fall. Increased precipitation likely in the form of rain and less moisture during critical growing period. Shallow soils with limited water holding capacity may have less water available for plant growth and create arid conditions.
Fire and other disturbances	Large stand replacement disturbances will restart succession and may alter the complexity of species at a given site. Less intense disturbance events may mimic current conditions. Regeneration post disturbance will be the driver of how fast forests change.
Ponderosa pine ( <i>Pinus ponderosa</i> var. <i>Scopularum</i> )	Intermediate adaptive strategy. Long lived seral adapted to soil moisture deficits in the growing season. Most heat and drought tolerant of the conifers on the Custer Gallatin National Forest. Deep rooting capacity and tolerance may allow expansion into Douglas-fir dominated sites on the montane unit (Minore 1979). Driest sites may inhibit plant establishment.
Douglas-fir ( <i>Pseudotsuga menziesii</i> )	Adaptive strategy on low to mid elevation sites is a specialist and on high elevation sites is a generalist. Highly adapted to large range of moisture regimes. With warmer temperatures on high elevation sites may expand into lodgepole pine dominated sites, but expansion could be limited to growing season frosts (Heineman et al 2003)
Lodgepole pine ( <i>Pinus contorta</i> )	Specialist adaptive strategy. Adapted to heterogeneous forested landscapes in mid to high elevations. Frost resistant in winter and during growing season. Competes with subalpine fir without disturbance and dominates following wildfire (Bartlein et al. 1997, Rice et al. 2012). With increased average temperatures and where cold does not limit its establishment it may retract from dry sites that may be favored by Douglas-fir (Minore 1979)
Subalpine fir ( <i>Abies lasiocarpa</i> ) and Englemann spruce ( <i>Picea engelmannii</i> )	Engelmann spruce has an intermediate adaptive strategy. Subalpine fir is drought intolerant and adapted to cool temperatures. Suited for cool moist high elevation sites. May expand into areas that are currently limited by cold conditions for establishment. Or when both temperature and precipitation increase the timberline conifer region may decrease in spatial extent (Shrag et al. 2008).
Whitebark pine ( <i>Pinus albicaulis</i> )	Generalist adaptive strategy. Adapted to cold, dry, high elevation sites. Longer warmer growing seasons could enhance regeneration establishment. At risk from white pine blister rust, mountain pine beetle, competition, drought and heat stress in the drier areas (Romme and Turner 1991, Shrag et al. 2008, Rice et al. 2012). As a generalist with its seed dispersal mechanisms and genetic quality it may colonize sites where other species cannot.

<sup>1</sup>Species possessing a generalist adaptive strategy are likely to fair better than intermediate and specialist with respect to climate change.

Table 41. Summarized assumptions/potential trends with climate change by habitat type group

Habitat Type Group	Assumptions/Potential Trends with Climate Change
Hot Dry and Warm Dry	<p>Dominated by Douglas-fir and/or limber pine, with some ponderosa pine and juniper on the montane unit.</p> <p>Warm dry type of pure ponderosa pine with some juniper on the pine savanna unit.</p> <p>Typically at lower elevations on dryer aspects with limited stocking.</p> <p>Natural fire regime characterized by low severity 0 to 35 year frequency; wildfires that occur in areas departed from this will experience reforestation needs.</p> <p>Mortality may occur from mountain pine beetle, Douglas-fir beetle, and western spruce budworm.</p> <p>Under a more arid climate, the higher energy aspects may trend towards bunchgrasses and shrubs.</p> <p>Douglas-fir on the montane unit and ponderosa pine on the pine savanna unit may persist in swales or protected areas and be lightly stocked.</p> <p>On the montane unit there may be a shift to ponderosa pine in some areas.</p> <p>Successful regeneration will be difficult on southerly and high energy slopes especially after wildfire.</p> <p>Ponderosa pine seed source is lacking in many areas due to fire and artificial reforestation will be needed for forest cover restoration.</p> <p>Cold temperature may limit extent of ponderosa pine in some elevations on the montane unit.</p> <p>On the montane unit limber pine sites may shift to open savannah.</p>
Moderately Warm Dry	<p>Typical sites on any aspect at lower elevations, and dry aspects at moderate elevations:</p> <p>Nearly pure Douglas-fir on dry aspects or Douglas-fir/lodgepole pine mix on more mesic aspects on the montane unit and pure ponderosa pine on the pine savanna unit.</p> <p>Areas departed from historic fire regime (low severity, 0 to 35 year frequency will have reforestation needs post wildfire.</p> <p>Bark beetle outbreaks which may be exacerbated by budworm defoliation, drought and overstocking may also experience reforestation needs.</p> <p>Exposed high energy sites may convert to savannah and bunch grass.</p> <p>Granitic soils are well drained and currently have lighter tree stocking due to poor water holding capacity may be intensified during the growing season with climate change. Low energy sites will probably support low stocking.</p> <p>Sedimentary soils with a clay component are deeper with a higher water holding capacity and may support a low tree density. Opportunities to plant ponderosa pine in mosaics where these deeper soils and more moist conditions occur.</p> <p>Typical sites on north aspects at low to moderate elevations with high amounts of available moisture:</p> <p>On the montane units these are dominated by Douglas-fir with varying amount of lodgepole pine, Engelmann spruce, and a shrub component. On the pine savanna unit these are pure stands of ponderosa pine restricted to low energy sites</p> <p>Departure from a historic fire regime (low severity with 0 to 35 year frequency or a low/mixed severity with 35 to 200 year frequency) will have reforestation needs post wildfire.</p> <p>Bark beetle outbreaks which may be exacerbated by western spruce budworm defoliation, drought, and overstocking will result in reforestation needs.</p> <p>Ponderosa pine will be favored on the montane unit currently dominated by Douglas-fir with warmer climate. This due to drier growing season and decrease in cold limitations currently limiting ponderosa pine.</p> <p>Douglas-fir may be preferred over lodgepole pine in cooler ecotone sites except where growing season frosts occur.</p> <p>Climate change could create favorable conditions for root disease where Douglas-fir vigor declines.</p> <p>On the pine savanna unit successful reforestation of ponderosa pine post disturbance (especially fire) will be on these moist sites.</p>

Habitat Type Group	Assumptions/Potential Trends with Climate Change
Cool Moist	<p>Dominated by Douglas-fir with varying amounts of lodgepole pine, Engelmann spruce, and a shrub component.</p> <p>Typically found on north aspects at low to moderate elevations with high amounts of available moisture.</p> <p>Areas departed from historic fire regime (low severity with 0 to 35 year frequency or a low/mixed severity with 35 to 200 year frequency) will experience reforestation needs post wildfire.</p> <p>Bark beetle outbreaks which may be exacerbated by budworm defoliation, drought, and overstocking may experience reforestation needs.</p> <p>With a warmer climate and longer growing season, these sites will remain relatively productive with Douglas-fir maintaining dominance (as is current) or increasing on drier aspects.</p> <p>Lodgepole pine will also be the dominant tree cover in many areas and generally regenerate successfully.</p> <p>Douglas-fir habitat types may replace subalpine fir habitat types in dominance on the more exposed aspects and dry ecotone sites.</p> <p>Subalpine fir will likely be more successful in establishment in draws and more protected areas.</p> <p>Dry exposed aspects likely will have low stocking densities.</p>
Cool Wet	<p>Comprised of riparian types found in stream bottoms or slopes with seeps and springs.</p> <p>Dominated by Engelmann spruce and lodgepole pine, with Douglas-fir on the drier sites and subalpine fir in some places.</p> <p>Reforestation needs may arise post wildfire in areas departed from the historic mixed severity fire regime.</p> <p>Bark beetle outbreaks which may be exacerbated by budworm defoliation, drought, and overstocking may contribute to reforestation needs.</p> <p>Sites are typically draws, flat areas, or drainage bottoms.</p> <p>Spruce and lodgepole pine may still establish successfully, depending on the effects of stand replacing event on the water table. Dependent on the gradient and soils, the water table may increase if there is sufficient water, with only the fringes drying out. Or if less water is available the water table could decrease and non-forest species could increase with the loss of tree cover.</p>
Cool Moderately Moist to Dry	<p>Moderate to moderately high elevations on gentle ground and all aspects:</p> <p>Nearly pure stands of lodgepole pine on cool sites. Areas without disturbance for over 100 years may contain Engelmann spruce, subalpine fir, Douglas-fir, and occasionally whitebark pine in the understory. Aspen may also be present.</p> <p>Stand replacement fire, bark beetles outbreaks which may be exacerbated by drought and overstocking generally result in reforestation needs.</p> <p>Lodgepole pine will likely be maintained as the dominant forest cover except on very dry aspects having granitic soils under drier climates.</p> <p>Douglas-fir will dominate when moisture is limiting for lodgepole pine on the driest exposures.</p> <p>Drier growing seasons may cause greater frequency of wildfire. Hot stand replacing wildfires may be common with smaller mixed intensity fires.</p> <p>Mountain pine beetle outbreaks will continue.</p> <p>Beetle outbreaks and more frequent wildfires may create more age class diversity on these landscapes.</p> <p>Aspen will regenerate but will likely be restricted to areas holding more soil moisture. The extent of aspen in this zone may be reduced or be less vigorous.</p> <p>Moist sites on generally on north aspects near water:</p> <p>Lodgepole pine generally dominates with subalpine fir, Engelmann spruce, and occasional Douglas-fir, whitebark pine, and aspen.</p> <p>Departure from a historic mixed severity fire regime will result in reforestation needs post wildfire.</p> <p>In addition, bark beetle outbreaks which may be exacerbated by budworm defoliation, drought, and overstocking will create reforestation needs.</p> <p>Reforestation success will depend on water table changes following disturbances. Elevated water tables may inhibit reforestation success. Cold air settling may also limit regeneration.</p>

Habitat Type Group	Assumptions/Potential Trends with Climate Change
	<p>Moderate to moderately high elevations driest of the Engelmann spruce and subalpine fir habitat types (scattered small stands, limited acreage):</p> <p>Lodgepole pine, Douglas-fir, Engelmann spruce, and subalpine fir are the majority of the tree species. Whitebark pine and limber pine are occasionally found.</p> <p>Like the other habitat type groups reforestation needs may arise from wildfire or bark beetle outbreaks which may be exacerbated by drought and overstocking.</p> <p>These sites will likely experience drier conditions during the growing season.</p> <p>Lodgepole will likely continue to dominate and in the dryer ecotones Douglas-fir may increase in abundance.</p> <p>After disturbance, sites with granitic soils and high exposure aspects will likely support sparse forested conditions.</p> <p>Limber pine may expand into some microsites that were previously too cold to establish.</p> <p>Whitebark pine or limber pine may be more favored dependent on soil types and cold limitations,</p>
Cold and Timberline	<p>Occur in highest elevation zones dominated by subalpine fir, spruce, lodgepole pine, and whitebark pine.</p> <p>In areas departed from a mixed fire regime reforestation needs may arise from bark beetle mortality and wildfire.</p> <p>Climate change and/or disturbances may transition some of these sites to non-forest conditions.</p> <p>Drier climate may make soil moisture the most limiting factor due to exposed slopes, high solarization, and shallow soils, possibly reduce the aerial extent of tree establishment.</p> <p>These sites may have the greatest opportunity for whitebark pine to establish and expand where there are adequate seed sources or by artificial planting.</p> <p>Cold is currently a major limiting factor for tree establishment and may still be on some aspects.</p> <p>Extremes in temperatures and snow loads may continue to limit tree establishment.</p> <p>A warmer climate may result in more fires, or larger fires in this zone.</p>

## Key Benefits to People

See Ecosystem Services – Timber Assessment Report (Thornburgh 2017).

## Forest Vegetation Drivers and Trends

The natural world is in a constant state of change. Ecosystem “drivers” are the dominant ecological or human- influenced processes that shape the ecosystem. “Stressors” are related and interconnected with drivers; they are agents that strain the ecosystem and can cause imbalances. For simplicity, henceforth drivers and stressors are collectively referred to as drivers. Some drivers, such as wildfire, occur quickly and cause rapid visible changes, while others such as succession result in slow, incremental change. Drivers interact in time and space. Changes in key drivers may affect the sustainability of forest landscapes and set the stage for increased tension among competing ecosystem services; the interaction of drivers may be the greatest source of complexity and uncertainty regarding the degree to which landscape patterns can be managed to sustain multiple ecosystem services in the face of change (Turner et al 2012)

The following drivers are considered important on the forested vegetation on the Custer Gallatin National Forest. Other processes such as flooding, decay and nutrient cycling, and windthrow also occur.

- Climate and climate change
- Vegetative succession
- Fire
- Forest insects and diseases

- Vegetation treatments
- Invasive species

Climate change, vegetation succession, insects and diseases, and vegetation treatments will be discussed below. The other drivers are being discussed in other assessment reports (Climate – Barndt 2016, Fire – Shea 2016, and Invasive Species – Reid 2016).

## Climate Change

### Existing Condition

Existing climate for the Custer Gallatin National Forest planning area is discussed and can be found in the climate section of the assessment.

Weather and climate varies at different spatial and temporal scales which makes climatic trends complicated and confusing. Weather is defined as the hourly, daily, weekly or monthly summaries such as temperature, precipitation, wind, and humidity observed at a given place or larger regional area. Weather can change rapidly at small, temporal scales and can vary spatially (north to south, east to west, and up or down in elevation). Climate is a statistical characterization of weather, averaged over many years. Climate variability is the variation in weather statistics over large regional areas and long periods of time and can be caused by underlying processes and external forces such as changes in patterns of ocean temperatures, solar radiation, volcanic eruptions, and increases in greenhouse gasses in the atmosphere. Climate change is a non-random change in climate that is measured over several decades or longer.

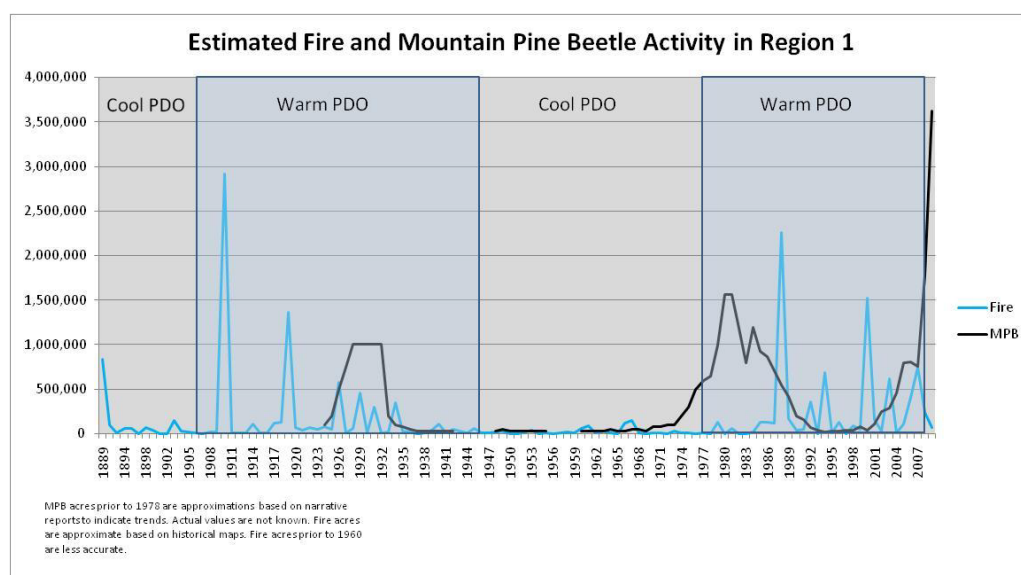
Climate strongly influences vegetation and ecosystem processes. Periodic variation in precipitation can initiate events such as droughts and flooding which alter vegetation directly, such as through mortality of trees, or indirectly, such as by increasing the probability and/or severity of disturbances. Over geologic time, changes in climate and disturbance regimes are a natural part of ecosystems; even so, as a consequence of climate change, forests may face rapid alterations in the timing, intensity, frequency, and extent of disturbances (Dale et al. 2001).

Climate influences vegetation directly and indirectly. Vegetation requires sunlight (energy) and moisture in addition to nutrients found in the soil. Systems on the Custer Gallatin National Forest are generally moisture-limited as opposed to energy-limited. That is, there is plenty of sunlight, but growth is limited by moisture. Warm/dry climatic periods generally result in slower growth and lower *site capability* (the ability of a site to support vegetation based on available resources) than cool/moist periods. Competition-based mortality increases during dry periods because there is less moisture available. Species extent and distribution are consequently impacted.

### Trend

Historically, the climate of the Northern Region has fluctuated between cool and warm periods. Climate is affected by multiple factors, including sea surface temperatures tracked by indices such as the Pacific decadal oscillation, El Niño southern oscillation, and the Atlantic multidecadal oscillation. The Pacific decadal oscillation tracks variations in sea surface temperature in the northern Pacific which tend to cycle approximately every 20 years (Zhang et al. 1997). Pacific decadal oscillation can help explain the cycles of some drivers such as wildfire. Severe fire years tend to occur when warm weather spikes follow cool wet weather cycles (USDA 2015b).

Climate has been the major driver of large fire years throughout the last 140-year period in the Northern Region (USDA 2015a). The relationship of the Pacific decadal oscillation and large fire years in Northern Region is well documented (Morgan et al. 2008). Drought is a common disturbance force that drives many ecosystem processes during warm periods (Vose et al. 2016). It is clear that drought and associated temperature changes can significantly influence outbreaks of forest insects (ibid). Figure 51 below depicts Pacific decadal oscillation periods along with the acres impacted by wildfire and mountain pine beetle activity in the NR from 1889 to 2007. From 1905 to 1945, the Pacific decadal oscillation was warm and the Region experienced high fire and insect activity. Conversely, the period from 1950-1980 was cool with low activity. Many acres in the Northern Region have been impacted by fires and mountain pine beetle in the warm Pacific decadal oscillation since 1980. Uncertainties exist regarding the acres affected by fires and insects, especially in earlier periods prior to consistent record keeping.



**Figure 51. Region 1 fire and beetle disturbance (acres affected) related to Pacific decadal oscillation (PDO) (USDA 2015a)**

Wildfire chronologies assembled from fire scars on tree rings and reconstructions of sea surface temperatures indicate the Pacific decadal oscillation may explain the decadal variation of fire activity in the Pacific Northwest whereas El Niño southern oscillation is thought to be linked to shorter term variation of fire activity in a single year or between years (Kitzberger et al. 2007). The combination of positive warm phases of both the Pacific decadal oscillation and Atlantic multidecadal oscillation seems to have a broad geographic influence as this may be responsible for drier conditions across the entire western U.S. (ibid). In the northern Rockies, the combination of a positive Pacific decadal oscillation during El Niño (combined warm phase) was significantly correlated with large-fire years based on data from 1700 to 1975 (Schoennagel et al. 2005). A multi-year positive El Niño index combined with a slightly above-average Pacific decadal oscillation may set the stage for large fire growth years in the northern Rockies as well (ibid). Morgan and others (2008) isolated eleven years from 1900 to 2003 that exceeded the 90th percentile in annual acres burned based on fire atlas data that included the northern Rockies; these fire years occurred when the Pacific decadal oscillation was positive and suggest there is a connection between spring and summer weather and climate with fire activity and acres burned. However, it is acknowledged that there have been conflicting findings of the effects of El Niño and Pacific decadal oscillation on regional fire years (Kipfmüller et al. 2012; Heyerdahl et al. 2008).

Considerable natural variation in climate occurred historically and will continue. Different climate models project differing rates of change in temperature and precipitation because they operate at different scales, have different climate sensitivities, and incorporate feedbacks differently. However, climate models are unanimous in projecting increasing average annual temperatures over the coming decades. Continued and/or increasing drought will likely further limit the carrying capacity of sites, resulting in altered composition, structure, or even lifeform (grass/shrub versus forest vegetation) especially on low elevation sites (Vose et al. 2016, USDA 2015b). Further, drought will likely also exacerbate vegetation drivers such as fire, insects, disease, and invasive species (Vose et al. 2016).

Recently the Northern Region has undertaken a state-of-the-art synthesis on climate change impacts on vegetation across the region. This effort, referred as the Northern Rocky Mountain Adaptation Partnership (NRAP), is currently in draft form (Halofsky et al. 2017). The Northern Rocky Mountain Adaptation Partnership integrated broad scale modeling results with a detailed synthesis of climate change literature for the Northern Region. A substantial amount of professional anecdotal and observational information helped with context. The purpose was not intended for a site level detail analysis or use, but to compile valuable information and synthesis for use to address broad concerns at the landscape level such as for this forest plan assessment.

Climate models that predict rapidly warming climates have a high degree of uncertainty (ibid). While there is little debate that atmospheric carbon dioxide is increasing and that this increase will cause major changes in climate (ibid), there is a great deal of uncertainty about the magnitude and rate of climate change. Although not specifically cited in this assessment there is a great deal of literature used for the Northern Rocky Mountain Adaptation Partnership and one of the findings was that the literature is inconsistent on the response of tree species to future climate.

Adaptive capacity (strategy) is the ability of a plant, species, or system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences (ibid). Sensitivity is the degree to which a system is affected, either adversely or beneficially, by climate variability or change. The effect may be direct or indirect. Vulnerability is the degree to which a system is susceptible to, and unable to cope with, the adverse effects of climate change, including associated climate variability and extremes (ibid). Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity.

The following section includes information from the Northern Rocky Mountain Adaptation Partnership (ibid) effort (compiled from best science) describing broad scale climate change effects, current condition/stressors, sensitivity to climate change, potential effects to climate change, adaptive capacity, and vulnerability for individual forest tree species found on the Custer Gallatin National Forest. Additionally these effects to broad forest vegetation types, landscape heterogeneity, timber production, and carbon sequestration are briefly discussed.

#### *Limber Pine (Pinus flexilis)*

- Broad scale climate change effect: Warming temperatures, anticipated increase in precipitation, less snow pack, variable precipitation during growing season.
- Current conditions and existing stressors: Reduced abundance due to exotic white-pine blister rust infections, native mountain pine beetle outbreaks, and continued fire exclusion.
- Sensitivity to climate change: Shade intolerant, early seral to pioneer species following fire or tree removal; difficulty in competing with other encroaching species on more productive sites;



Little to no reproduction at low tree densities (lack of effective pollination cloud) and those seeds that are produced have increased likelihood of inbreeding.

- Potential effects of climate change: Increased growth; larger seed crops; increased seed dispersal into burned areas due to bird dispersal; lower seed germination due to warmer, drier conditions; loss of ectomycorrhizal associations, increased competition from wind-dispersed conifers; less blister rust infection due to higher temperatures and lower relative humidity disrupting the blister rust cycle; except in wave years; higher blister rust and dwarf mistletoe infections on eastside where precipitation is projected to increase; large and intense wildfires could threaten seed sources.
- Adaptive strategy: Intermediate adaptive strategy largely driven by timing of pollen cloud dispersal (elevational effect); highly adapted to populating the burned areas predicted for the future due both to wind and corvid-mediated dispersal; poor competitor on more productive sites, if future fires are larger, more severe, there will be less competition from other subalpine conifers; possesses moderate genetic variation (capacity) in blister rust resistance; major gene resistance to blister rust has not been identified in several studies of interior populations, warmer temperatures favor expansion of alternate host species (currant, lousewort and Indian paintbrush); little to no opportunity to hybridize with western white pine due to non-overlapping species distributions, cannot hybridize with whitebark pine; very high risk of loss of disjunct and isolated populations due to genetic drift, ineffective pollen cloud, and substrate availability.
- Vulnerability assessment ratings: magnitude of effects – moderate; likelihood of effects – moderate.

#### *Aspen (Populus tremuloides)*

- Broad scale climate change effect: Warming temperatures, decreasing snowpack, increase in severity and frequency of wildfires.
- Current conditions and existing stressors: While there are stable climax aspen communities, most aspen is a fire-maintained, early seral component of a forested community; stands are declining in number and size; stressors include competition with and shading by conifers, typically due to fire exclusion, domestic and native ungulate herbivory, and increasing temperature coupled with declining precipitation; reduction of soil moisture may cause severe water stress which reduces aspen's ability to survive (e.g., sudden aspen decline) and to reproduce both vegetatively and by seed, thereby reducing genetic variability.
- Sensitivity to climate change: Sensitivity varies based on site characteristics, primarily soil moisture and solar radiation; it is mostly shade-intolerant; ubiquitous across most of North America; aspen is most persistent on sites with high solar radiation coupled with moist to wet soils; it does not tolerate extended drought; highly fire-adapted and regenerates abundantly after stand-replacing fire, although it can regenerate in conifer dominated stands in some settings ; it will persist or possibly increase with warmer temperatures as long as there is sufficient soil moisture; fringe communities may succumb to sudden aspen decline with long-term and severe water deficit, which will kill the roots.
- Potential effects of climate change: Communities on warmer, drier sites could decrease due to water deficit; some stands may have significant mortality with little or no regeneration due to herbivory; sudden aspen decline has been associated with severe, prolonged drought, particularly in aspen stands that are on the fringe of the species' distribution (warmer and drier sites than those typically considered optimal for aspen persistence); fewer and smaller stands

and of those that persist, there will be increased plant stress due to increased severity of summer droughts; increased fire frequency may likely favor aspen regeneration by removing shading conifers; younger stands (less than 40 years old) may be more resilient to drought and frequent fires could favor aspen on moister sites; severe fire may kill shallow root systems and eliminate aspen in some hotter and drier sites; growth may increase because photosynthetic rates appear to increase more in aspen than other tree species as atmospheric carbon increases, but this may be offset by increased drought stress and increased atmospheric ozone, which reduces photosynthesis and may increase susceptibility to insects and disease; higher herbivory (browsing) on regenerating stands is possible as adjacent upland vegetation senesces and desiccates earlier in the growing season; areas with mountain pine beetle-caused conifer mortality (especially in lodgepole pine) may release aspen and regenerate once the conifer canopy is removed; conifers use more water than aspen so aspen stands mean more stream flows; aspen forms natural fuel breaks that can be used effectively in fire management; pathological rotation is short-lived.

- Adaptive strategy: Aspen has the widest distribution of all trees on the Custer Gallatin National Forest; it is circumpolar across multiple continents; it is highly susceptible to many insect and diseases; with a warmer climate gypsy moth may have greater impacts and cause possible mortality; aspen distribution may shift upslope or to northeast (cooler, moister) aspects if drought and repeated fire causes mortality on the warmer, drier sites. Riparian aspen communities will likely persist or increase in extent, particularly if the sites remain moist throughout the growing season and increased fire burns the riparian zone, killing conifers. Fire will favor aspen, but prolonged drought will cause mortality. Younger aged stands (less than 40 years) may be more resilient to drought; long distance dispersal by light seed may enhance its ability to colonize recently burned areas and establishment of young (sapling, pole) stands; this will vary based on winter snowpack, and amount and time of melt (and associated peak flows) but only if there is sufficient moisture.
- Vulnerability assessment ratings: Magnitude of effects – moderate; likelihood of effects – high.

*Cottonwood (Populus tricarpa, P. angustifolia, P. deltoides)*

- Broad scale climate change effect: Warming temperatures; decreasing snowpack; increase in severity and frequency of wildfires.
- Current conditions and existing stressors: There has been a reduction in area due to conversion and development of floodplains; composition and structure of cottonwood forests have been altered due to changes in flow regimes; structural alteration (typically simplification) of the channel (for example, levees, bank armoring structures) has likely contributed to channel widening, or channel incision and loss of floodplain interaction; non-native trees which are more drought tolerant are already present along rivers and streams in eastern Montana; increased drought stress will likely favor these species over cottonwood; additional stressors include roads, along with domestic and native ungulate browsing (particularly on young cottonwoods).
- Sensitivity to climate change: All species of cottonwood require saturated, but aerobic substrates and full sunlight to germinate and persist; any alteration of hydrologic flow regime (e.g., timing, magnitude and duration) will affect floodplain interaction and plant available water that may reduce recruitment and establishment of seedlings (cottonwoods regenerate primarily by seed); decreased stream flows and floodplain interaction may result in a shift in streamside vegetation to upland species, along with reduced growth and regeneration, and increased mortality of cottonwood; since cottonwoods are shade intolerant (require full sunlight) any conifers that

establish on the drier fluvial surfaces will grow tall enough to eventually shade out the cottonwoods; as snowpacks decline and melt earlier, peak flows will be reduced and variation in discharge will decline, leading to a loss of various fluvial (depositional) surfaces along the stream, on which cottonwood germinate; the system becomes less complex; there may be fewer recruitment events; in addition, there may be a shift in timing of peak flows to earlier in the season, before cottonwood seed is viable for germination, resulting in both decreased germination and establishment of young cottonwoods; increased demand for water (additional diversions, reservoir expansions) and increased browsing pressure (adjacent upland vegetation senesces and desiccates earlier in the growing season) may also lead to a decline in cottonwood; sizes of cottonwood forests may decrease as these fluvial surfaces are less frequently inundated; there may be little to no recruitment of young cottonwoods.

- Potential effects of climate change: Timing of flooding is critical to germination success and establishment of young (sapling, pole) cottonwoods both diminished; this will vary based on winter snowpack, and amount and timing of snowmelt (and associated peak flows); seedlings establish on moist to wet bare mineral soil, typically on stream bars, in full sunlight; as the snowpack declines and melts earlier, there will be reduced, more stabilized flows (loss of extreme high and/or low flows) and/or a shift in timing of peak flows to earlier in the season, before cottonwood seed is viable for germination); with earlier peak flows and less discharge, germination success is diminished; increased demand for water (additional diversions, reservoir expansions) and increased browsing pressure (as adjacent upland vegetation senesces and desiccates earlier in the growing season) will also likely lead to a decline in cottonwood.
- Adaptive strategy: Plains cottonwood may be more persistent due to greater plant available soil water in the unsaturated zone (as a result of finer textured soils). Black and narrowleaf cottonwood typically occur in coarser substrate which will become drier as flows are lower and recede earlier than in the past, or are attenuated due to diversions. Seedling and sapling mortality may increase in these species. Plains cottonwood regeneration occurs with episodic flooding, whereas black and narrowleaf cottonwood typically regenerate with 1-3 year bankfull flow return intervals; therefore plains cottonwood will likely be more adapted to irregular flows (in timing, magnitude and duration) that may occur with climate change.
- Vulnerability assessment ratings: Magnitude of effects – moderate; likelihood of effects – moderate to high.

#### *Douglas-fir (Pseudotsuga menziesii)*

- Broad scale climate change effect: Increase in temperature causing increase in soil moisture deficits and less available water especially at lower elevation dry sites.
- Current conditions and existing stressors: Increase in tree density has increased risk of mortality from a large fire standpoint which will also limit regeneration and species distribution locally.
- Sensitivity to climate change: Sensitive to increasing temperatures and increasing soil moisture deficits, this will predispose Douglas-fir to other related mortality agents such as insect and disease.
- Potential effects of climate change: At lower elevation southerly aspects expect ponderosa pine to be better able to cope with moisture deficits and disturbance such as fire, spruce bud worm, less seed source due fire size and due to cone production problems with spruce bud worm, mesic sites expect increase in mortality due to root disease, higher elevation southerly slopes may

provide increased climate suitability for Douglas-fir; large and intense wildfires could threaten seed sources.

- Adaptive strategy: Specialist adaptive strategy at low to mid elevations, generalist adaptive strategy at higher elevations; no opportunity of hybridizing with coastal Douglas-fir subspecies since distributions do not overlap; highly adaptive to a large range of moisture and temperature gradients. In moist forest settings Douglas-fir is limited to a relatively short-lived seral species due to the influence of root diseases; With warming temperatures and a possible decrease in summer moisture drought conditions, Douglas-fir may increase along with an increase abundance of associated stressors; vulnerable to uncharacteristic fire behavior and severity due to increased densities; increase in susceptibility to Douglas-fir bark beetle mortality uncertain but probably an increased activity; moderate change in species distribution expected away from driest margins. High potential for natural regeneration failure due to reduced seed source from large wildfires and difficult micro climate especially on southerly exposures at lower elevations with increasing moisture deficits expected. On moist sites (mixed mesic forest), increases in root disease mortality due to increasing moisture stress on sites where ponderosa pine occurred historically. Less carbon sequestration expected in Douglas-fir in those forest settings; there is a high likelihood of change in local distribution due to moisture deficits and fire severity.
- Vulnerability assessment ratings: Magnitude of effects – high; likelihood of effects – high.

*Engelmann spruce (Picea engelmannii)*

- Broad scale climate change effect: Increased disturbance frequency and severity; highly variable weather and climate; decreasing snowpacks; lengthening growing seasons.
- Current conditions and existing stressors: Spruce is usually associated with fir in the Northern Region; it occurs as a minor to major component of many subalpine stands and only dominates in wetland or special land types; fire exclusion has increased abundance of this species on many subalpine and upper subalpine landscapes; many current stands have high densities and trees may be stressed from competitive interactions resulting in increasing susceptibility to disturbances; increasing drought could further exacerbate competitive stress and increase mortality.
- Sensitivity to climate change: Like fir, spruce is highly susceptible to changes in climates; it is not as an aggressive competitor and often is only a minor portion of a stand; it is highly vulnerable to drought; it can quickly regenerate in severely burned microsites providing there are seed sources; highly susceptible to windthrow and wind damage.
- Potential effects of climate change: Loss of spruce in the drier portions of its range, especially in those seasonal moist sites that will now be dry; not well adapted to fire so major declines are expected in burned areas, but these declines may be offset by increased regeneration on burned areas with mineral soil substrates; continued fire suppression activities may maintain spruce on the landscape but it may be at lower levels due to increased drought; it may increase in the upper subalpine when snowpacks become consistently lower and soil becomes drier thereby allowing spruce to encroach into glades, meadows, and balds.
- Adaptive strategy: Intermediate adaptive strategy with strong opportunities to hybridize with white spruce, hybrids may be more suited to future climates and hybridization is another key driver in speciation.
- Vulnerability assessment ratings: Magnitude of effects – moderate; likelihood of effects – moderate.

*Green ash (Fraxinus pennsylvanica)*

- Broad scale climate change effect: Warming temperatures, decreasing snowpack, increase in severity and frequency of wildfires.
- Current conditions and existing stressors: Domestic and native ungulate herbivory has affected both structure and composition of these communities.
- Sensitivity to climate change: Green ash has broad ecological amplitude and can survive droughty conditions, but persists optimally in moist sites; as soil moisture declines, marginal sites may become less favorable for regeneration and survival of young trees; there will probably be increased vegetative regeneration and decreased production of seedlings following fire- fire often kills green ash seed on or near the soil surface, restricting seedling recruitment to surviving seed producing trees.
- Potential effects of climate change: Green ash may benefit from increased temperatures; seedling growth may increase with increasing soil temperatures; after increased fires, green ash has both root crown and epicormic sprouts, and both are typical following disturbances such as fire; fire may be very important in woody draws and riparian areas; since woody draws are typically long and narrow, even though they are more moist than surrounding uplands, they likely were also burned during frequent fires in the surrounding grasslands. Thus ash is well-adapted to fire; low-severity fires might promote regeneration by thinning stands and stimulating sprouting (the primary response to fire); browsing pressure will likely increase with increased drought, as upland grasses and forbs desiccate and senesce earlier, or are replaced by invasive, less palatable species.
- Adaptive strategy: Since green ash communities are already fire adapted (most associated species display some fire tolerance and/or post-fire sprouting ability), increased fire will likely not affect most of the moister communities. However, those communities associated with either ephemeral drainages (for example, woody draws) or moist upland microsites (for example, northeast facing residual snow-loaded depressions) may experience more drought stress as snowpack declines and melts sooner, and regeneration may decrease, eventually resulting in loss of those communities.
- Vulnerability assessment ratings: Magnitude of effects – moderate; likelihood of effects – high.

*Lodgepole pine (Pinus contorta)*

- Broad scale climate change effect: Increasing temperatures; longer droughty periods; increasing fire occurrence, frequency, and severity; and increased productivity.
- Current conditions and existing stressors: Advancing succession due to fire exclusion is contributing to declines in lodgepole pine in many areas; current increases in burn areas are creating many new lodgepole stands and some may become dense thickets; increased drought may exacerbate stress from other factors including competition, endemic insects and diseases, and wind; warming temperatures may heighten bark beetle activity resulting in more frequent and severe epidemics.
- Sensitivity to climate change: Shade intolerant conifer that has a wide climatic amplitude in subalpine areas; exists on a wide variety of soil types and may be the only species to inhabit infertile and well drained sites; moderately drought tolerant; reproductive success depends on level of serotiny; well adapted to colonize post-burn environments; highly susceptible to bark

beetles, especially when in stress from endogenous and exogenous factors such as competition, fire-damage, and drought.

- Potential effects of climate change: Longer drought periods and warmer temperatures may decrease growth and regeneration on the driest sites (lower elevation lodgepole stands); lodgepole is well adapted to increases in fire occurrence and size depending on level of serotiny, but it may be eliminated from sites where fires reburn stands before established seedlings and saplings become reproductively mature; In mesic subalpine sites, continued fire exclusion coupled with higher productivities will heighten competitive interactions and put more lodgepole pine into stress thereby increasing mortality, insect and disease vulnerability, canopy and surface fuels, and accelerating succession toward subalpine fir; conversely, increasing fire could expand lodgepole pine occurrence, even when fires are large and severe; increasing insect (i.e., bark beetles) outbreaks may further acceleration towards non-host, shade tolerant species.
- Adaptive strategy: Specialist adaptive strategy; especially adapted to occupy post-burn landscapes that may be more common in the future; highly susceptible to increasing bark beetle outbreaks, especially on landscapes dominated by mature individuals; Varying levels of serotiny allow the species to both occupy new upper subalpine environments while also regenerating after fire; its intolerance of deep droughts may reduce its capacity along the xeric edges of its current range; High heterogeneity at landscape scales may mitigate adverse impacts from fire and mountain pine beetles.
- Vulnerability assessment ratings: Magnitude of effects – moderate; likelihood of effects – moderate.

*Ponderosa Pine (Pinus ponderosa var. scopularum)*

- Broad scale climate change effect: Increasing temperatures; deeper and longer droughts; increasing fire severity and occurrence; potentially shorter growing seasons and longer dormant seasons.
- Current conditions and existing stressors: Higher than historical tree densities.
- Sensitivity to climate change: Decreases in western gull rust damage; competitive capacity will increase; fire effects uncertain; highly vulnerable to loss of disjunct and isolated populations, declining precipitation and variable spatial and temporal pattern may cause declines in regeneration, except in eastern portion of northern region where precipitation is expected to increase; increases in mountain pine beetle outbreaks; advancing competition, increasing western pine shoot borer occurrence; large and intense wildfires could threaten seed sources
- Potential effects of climate change: Generalist adaptive strategy; high phenotypic plasticity; early- to mid-seral species; moderate shade-tolerance; well-adapted to drought.
- Adaptive strategy: Generalist adaptive strategy; high phenotypic plasticity; better adapted to drought
- Vulnerability assessment ratings: Magnitude of effects – low; likelihood of effects – low.

*Subalpine fir (Abies lasiocarpa)*

- Broad scale climate change effect: Increased disturbance frequency and severity; highly variable weather and climate; decreasing snowpacks; lengthening of growing seasons.
- Current conditions and existing stressors: Fire exclusion has increased abundance of this species on many subalpine and upper subalpine landscapes; many current stands have high densities and

trees may be stressed from competitive interactions resulting in increasing susceptibility to disturbances; increasing drought could further exacerbate competitive stress and increase mortality.

- Sensitivity to climate change: Highly vulnerable to subtle changes in climate; shade tolerant species that is an aggressive competitor in subalpine areas; uniquely adapted to quickly occupy gaps in subalpine forest canopies; relatively intolerant of drought; unable to mature when seasonal drought is common; not adapted to disturbance, especially fire, with high mortality even after low severity fires; frequent cone crops.
- Potential effects of climate change: Longer growing seasons and reduced snowpacks will increase regenerative success, especially in those high elevation areas where snow historically controlled regenerative success; higher productivity in subalpine forests may increase regeneration and species densities, eventually resulting in high competitive stress making these fir stands vulnerable to high mortality and therefore less resilient; declines of the species on drier sites may result from new drought regimes reducing regeneration success; increases of the species on moister sites will result from increased regeneration and competitive advantages; fir may gain in upper subalpine and timberline environments that are controlled by snow dynamics; subalpine fir could also increase as it replaces rust- and beetle-killed whitebark pine, yet whitebark pine can also act as a nurse crop to facilitate subalpine fir establishment; increased fire would decrease fir throughout the Northern Region; the future of subalpine fir would depend on both fire suppression levels coupled with climatic responses.
- Adaptive strategy: Generalist adaptive strategy; increasing fire will dramatically reduce subalpine fir populations to historical levels; fire exclusion may foster subalpine fir encroachment into lodgepole pine and whitebark pine late seral stands; increasing temperatures may increase fir growth and accelerate succession toward fir-dominated stands, however, as competition increases, the warmer climates may facilitate increased mortality from insects and disease as trees become more stressed from high densities.
- Vulnerability assessment ratings: Magnitude of effects – moderate; likelihood of effects – moderate.

#### *Whitebark pine (Pinus albicaulis)*

- Broad scale climate change effect: Warming temperatures, lower snowpacks, highly variable weather, increasing fires in both intensity and severity, increasing insect and disease outbreak frequencies and severities; increase in populations of mountain pine beetle through possible one generation per year shifts.
- Current conditions and existing stressors: Reduced abundance due to exotic white-pine blister rust infections, native mountain pine beetle outbreaks, and continued fire exclusion; survival due to cold hardiness in seedlings and saplings in frost pockets and swales.
- Potential effects of climate change: Inability to compete with encroaching conifers due to low growth rates, moderate shade intolerance, and seed dispersal characteristics. Little to no reproduction may occur once tree densities are low; long-lived species that lasts through climate epochs.
- Sensitivity to climate change: Inability to compete with encroaching conifers due to low growth rates, moderate shade intolerance, and seed dispersal characteristics. Little to no reproduction may occur once tree densities are low; long-lived species that lasts through climate epochs.

- Adaptive strategy: Highly adapted to populating the greater burned areas predicted for the future due to bird-mediated dispersal; if future fires are larger, more severe, there will be less competition from other subalpine conifers; ability to survive fire better than its competitors; moderately shade tolerant so it can exist in competition with limited cone crops; delayed germination adaptation may mitigate warmer, drier conditions; possesses moderate to high genetic variation (capacity) in adaptive traits (blister rust resistance, late winter cold hardiness and drought tolerance), as well as phenotypic plasticity to respond to climate change. Warmer temperatures favor expansion of alternate host species (currant, lousewort, and Indian paintbrush). No opportunity to hybridize with another stone pine and cannot cross with limber pine where species distributions overlap; high risk and loss of disjunct and isolated populations; more drought tolerant than its associates; long distance bird dispersal will increase regeneration potential as more of the landscape burns.
- Vulnerability assessment ratings: Magnitude of effects – high; likelihood of effects – high.

### *Landscape heterogeneity*

- Broad scale climate change effect: Increased productivity causing accelerated succession; increases in disturbance frequency and extent; highly variable drought intensity and extent; migration of species to new habitats; changes in magnitude, season, and variability of water availability.
- Current conditions and existing stressors: Ninety years of fire exclusion coupled with past management activities (for example, grazing) has reduced landscape heterogeneity.
- Sensitivity to climate change: Landscape heterogeneity is highly susceptible to subtle shifts in climate because it is the reflection of the interaction of vegetation dynamics with disturbance regimes, topography, and land use. Small changes in climate may facilitate large changes in disturbances or vegetation dynamics causing new landscape mosaics.
- Potential effects of climate change: Increased fire may both increase and decrease landscape heterogeneity. Wildfires and wildland fire use fires may create patchworks of fire severity types across burned areas that will increase heterogeneity and therefore landscape resilience, but some fires may burn fire-excluded landscapes with high severities causing atypical large patches of high plant mortality that may decrease heterogeneity. While large, severely burned patches occurred in historical fires, the frequency and size of these patches may be different today. The highly variable species migration rates into areas with new climates may increase heterogeneity, but the rapidly changing climates may only facilitate generalist species thereby decreasing heterogeneity.
- Adaptive strategy: Since heterogeneity is an expression of disturbance, vegetation, and climate interactions it really is dependent on other factors to determine its adaptive capacity.
- Vulnerability assessment ratings: Magnitude of effects – moderate; likelihood of effects – high.

### *Timber production*

- Broad scale climate change effect: Higher temperatures may likely extend fire season and reduce forest inventory on areas suitable for timber production. Some increase in productivity may occur at mid to higher elevations; however increase in fire may reduce timber production opportunities.
- Current conditions and existing stressors: Composition shift causing reduced productivity is in southerly exposures Region wide. Risk of uncharacteristic fire severity is very high due to



uncharacteristic high forest density which will reduce timber production opportunities especially in dry forest areas.

- Sensitivity to climate change: Sensitivity high on southerly exposures Region wide due to increasing moisture deficits and increase in uncharacteristic disturbance such as severity and extent of fire and root disease.
- Potential effects of climate change: Expect some theoretical increase in production at mid and higher elevations due to warming temperatures. This could be offset overall by losses due to root disease and increase in fire severity across the areas suitable for timber productions in Forest Plans.
- Adaptive strategy: Productivity could increase at higher elevation sites; high exposure due to species composition changes and risk to increased disturbance.
- Vulnerability assessment ratings: Magnitude of effects – moderate; likelihood of effects – high.

### *Carbon sequestration*

- Broad scale climate change effect: Increased fire; increasing drought; productivity gains and losses.
- Current conditions and existing stressors: Past policies of fire exclusion have created late seral landscapes that sequester little carbon; past timber activities may have created younger stands that sequester more carbon; increasing disturbances (fire, insect, and disease) has caused short-term losses in carbon sequestration.
- Sensitivity to climate change: Carbon sequestration is very sensitive to climate change impacts on vegetation and disturbance; Rates of carbon sequestration are going to largely depend on the rate of burning in the future and the gains and losses of productivity in NR ecosystems; productivity gains and losses need to be evaluated at large spatial and temporal scales to understand future carbon dynamics.
- Potential effects of climate change: Fire exclusion will tend to push most ecosystems into later successional stages where sequestration rates are minimal; burning from controlled and uncontrolled wildfires and prescribed burning will cause short-term losses but the high productivity of the developing early seral stands may increase sequestration for decades; sites that were historically dry will probably experience decreases in production and carbon sequestration in the future, while those mesic sites that experience abundant water (for example, subalpine, upper subalpine, timberline) may experience increases in productivity.
- Adaptive strategy: All ecosystems have an inherent capability to store carbon and the rate and capacity of carbon storage depends on plant productivity and disturbance with the maximum levels of productivity dependent on climate while the instantaneous levels of productivity depend on successional stage or time since disturbance; many modeling studies have shown that many areas in the Northern Region will actually increase productivity and increase sequestration rate and magnitude; the delicate balance between disturbance and climate coupled with land management will dictate where sequestration will increase and where it will decrease; it is important to know that over the long term (centuries), sequestration is near zero (disturbance and respiration losses are balanced by productivity gains).
- Vulnerability assessment ratings: Magnitude of effects – high; likelihood of effects – moderate.

*Dry ponderosa pine and Douglas-fir forests*

- Broad scale climate change effect: Increase in temperature causing increase in soil moisture deficits and less available water especially at lower elevation dry sites.
- Current conditions and existing stressors: Increases in density has put at risk increased mortality from a fire severity standpoint.
- Sensitivity to climate change: Sensitive to increasing temperatures and increasing soil moisture deficits; this will predispose Douglas-fir to other related mortality agents such as insect and disease; this may give ponderosa pine an advantage on these settings.
- Potential effects of climate change: At lower elevation southerly aspects expect ponderosa pine to be better able to cope with moisture deficits and disturbance such as fire, spruce bud worm; less seed source due fire size and due to cone production problems with spruce bud worm; mesic sites expect increase in mortality due to root disease; higher elevation southerly slopes may provide increased climate suitability for Douglas-fir while ponderosa pine will be favored at lower elevations; patches size will increase due to severe fire if density reductions are not implemented.
- Adaptive strategy: Douglas-fir is highly adaptive to a large range of moisture and temperature gradients. Ponderosa pine adapted to settings that are moisture limited and can grow well where moisture is less limited; exposure of Douglas-fir to increasing moisture deficits may change composition to more ponderosa pine; increasing moisture deficits will give ponderosa pine the advantage on dry forest settings due to fire, insects, and disease.
- Vulnerability assessment ratings: Magnitude of effects – high; likelihood of effects – high.

*Lodgepole pine and aspen mixed conifer forests*

- Broad scale climate change effect: Increasing temperatures; longer droughty periods; increasing fire occurrence, frequency, and severity; increased productivity.
- Current conditions and existing stressors: Many stands of this type are succeeding to subalpine fir-spruce due to fire exclusion; aspen has been declining due to lack of fire and increasing drought.
- Sensitivity to climate change: This type is more sensitive to management actions than climate in that continued fire exclusion will ensure their decline; this type thrives with fire and will even survive insect and disease outbreaks if fire is present on the landscape.
- Potential effects of climate change: This cover type actually could expand in the future with increasing fires and the warming of the subalpine; disturbances may eliminate competing conifers and facilitate serotiny-aided lodgepole pine regeneration; aspen may decline on the drier parts of its range, but could increase and make major advances into the subalpine as fires burn competing conifers and temperatures moderate creating favorable climates; if fires are too frequent, this cover type may be replaced by semi-permanent shrub-herb, but as long as fire return intervals are greater than the reproductive age, lodgepole and aspen should prevail; as fires increase, more areas in this type will be early seral creating more heterogeneous landscapes with more patches of pine and fir mixed with aspen.
- Adaptive strategy: This type has the capacity to absorb climate changes and either remain constant or expand into the upper subalpine; losses in aspen due to drought may be offset by gains in lodgepole pine, especially after fire; there may be long-term migrations of this type to higher elevation areas with increasing disturbance.

- Vulnerability assessment ratings: Magnitude of effects – moderate; likelihood of effects – high.

#### *Whitebark pine-spruce-fir forests*

- Broad scale climate change effect: Declining snowpacks; increasing fire; increasing temperatures.
- Current conditions and existing stressors: This type is probably increasing in the NR from effective fire exclusion; losses in whitebark pine are successional replaced by fir-spruce; the low elevation spruce-fir types are becoming more dense and crowded.
- Sensitivity to climate change: This type might not be as sensitive as other more xeric sites to direct climate change impacts because there is abundant water, and predicted increases in both regeneration and growth may actually increase its climate resilience; increasing fires may cause a shift to more early seral communities and if whitebark pine populations were not experiencing rust outbreaks, these early seral communities would probably be dominated by whitebark pine.
- Potential effects of climate change: This type may contract into the future due to several interacting factors – whitebark pine will continue to decline due to rust and beetle outbreaks, spruce-fir forest may decline due to increased fire and reduced soil water; this site could be replaced by lodgepole-aspen in the drier parts of the NR; if planting and restoration activities are conducted, whitebark pine could make major gains into the increasing burned areas thereby replacing spruce-fir and limiting the contraction of this type; low elevation spruce-fir stands are probably going to move towards the western larch/mixed conifer type because of prolonged droughts and increasing temperatures, especially after fires.
- Adaptive strategy: This type may have the capacity to respond favorably to changes in climate but the depressed populations of whitebark pine coupled with the increasing fire may result in short-term losses of this type; however, if rust-resistant whitebark pine are planted and restoration activities are implemented, whitebark pine can easily dominate on these sites, especially if fires are large and severe, and whitebark pine may be able to make advances into the timberline; continued fire exclusion will probably aid in keeping this type somewhat static, and it may encroach on lower timberline sites if no fires are allowed.
- Vulnerability assessment ratings: Magnitude of effects – high; likelihood of effects – high.

Climate change is one of many challenges facing land managers in management of the forest vegetation and integrating climate change considerations into current management operations is preferable to a climate-centric management strategy. Mitigating past ecosystem damage (for example, fire exclusion and non-native introductions) and restoring fire-prone ecosystems can both improve ecosystem function and create forests that will be resilient in a warmer climate (USDA 2015b). Fire-prone forests have already experienced variation in past climate and have broad amplitudes of resilience with respect to climate (ibid). However, the Custer Gallatin National Forest will have places where climate change may be the primary (for example, drought at lower tree line) challenge.

#### **Information Needs**

Predicting climate change and its effects on vegetation and disturbance processes comes with a high degree of uncertainty based on inconsistent and contradictory studies. There are still many unknowns in ecosystem science. These uncertainties and unknowns when considered with the best science today and the techniques and inputs used in climate models present a range of possible future scenarios. If new climate change data or new models become available, or new data is used for existing models predictions could change. What is important is that as we move forward with management based on the current best science that we implement a monitoring strategy to accommodate new science and

utilize adaptive management. Without monitoring and continued research it may be impossible to know the magnitude and trend of climate change effects on vegetation. Future land management planning will be complete only if a plan for monitoring proposed actions is included.

## **Vegetative Succession**

Succession is the progression of change in composition, structure, and processes of a plant community through time (Winthers et al. 2005). It is based on the concept that every species has a particular set of environmental conditions under which it will reproduce and grow. As long as these conditions remain fairly constant, the species will flourish. Plants impact their environments and each other, and this causes the community to change over time. The successional process follows a pathway with major steps referred to as a seral or successional stage. In a simplified model for a forest, early successional stages typically follow a stand-replacing disturbance (for example, fire), which kills all or a portion of existing plants while leaving the physical environment intact. Trees and other plants start re-colonizing the site to fill up available growing space; this is also known as the establishment phase of stand development. Then, a series of intermediate successional stages follows, referred to as mid and late successional stages, where established species grow larger and denser based on site capability to make full use of resources. During these stages, new plants may be inhibited by high site occupancy or initiated in opening gaps as competition based mortality occurs. Changes in environmental conditions and competition for limited resources cause some species to decline and others to expand. The classical model of succession culminates in the climax community, a state of relative stability in composition, structure, and function, with all existing species able to perpetuate themselves without catastrophic disturbance.

This description of successional stages and associated forest characteristics is an oversimplification of what is in reality a far more complex and tangled web of inter-relationships between site conditions, vegetation and the ecosystem drivers and stressors. Highly diverse forest conditions can occur within any one successional stage and age. Time spent within a stage varies, and transition between stages is often gradual (except in the case of a stand-replacing disturbance that initiates the early successional stage). The abiotic conditions of a site (for example, soils, aspect, and climate) and the disturbance types and patterns are key to understanding the different vegetation communities that may occupy the site and their characteristics over time.

## **Trend**

Plant species are often distinguished as playing either an early or late/climax successional role. Species that have traits that enable rapid colonization and domination of a site after a disturbance are called early successional. They are typically less shade tolerant, able to flourish under full or nearly full sunlight, and have rapid early height growth. Ponderosa pine, lodgepole pine, aspen, and whitebark pine are the major early successional tree species on the Custer Gallatin National Forest. Late successional tree species, or climax species, are typically shade tolerant, capable of reproducing and growing in dense shady conditions.

Engelmann spruce and subalpine fir are the major climax tree species on the Custer Gallatin National Forest. To an extent most species can play multiple successional roles depending on site conditions and the other species present. This is particularly true of Douglas-fir on the Custer Gallatin National Forest, which functions as both an early and late successional species depending on the site.

Recognizing the potential successional pathways of plant communities is important; however, in disturbance-prone ecosystems the climax state may rarely if ever be achieved because succession is

commonly interrupted by drivers such as wildfire. Fire influences succession in most vegetation types on the Custer Gallatin National Forest. An important feature is the influence of long-lived, fire tolerant early successional species such as ponderosa pine, whitebark pine, and Douglas-fir which are able to persist for centuries. In many areas, climax conditions are uncommon due to the long-term survival of these early successional species that tolerate low or moderate severity fire. They grow large and become prominent features of the overstory canopy, providing structural components of late successional and old growth forest. Because fire often maintains specific species or vegetation types adapted to fire, fire exclusion has altered successional trajectories in some locations and habitats. Recent large stand replacement uncharacteristic fires on both the pine savanna and montane units have reduced these long lived components and reset the successional stage.

### **Information Needs**

No additional information is needed. The trend of successional trajectories is explored for ecosystem characteristics in sections above.

### **Forest Insect and Diseases**

Insects and diseases are important ecosystem drivers as they can influence vegetation on a local and landscape level. There are many insects and diseases that affect the forested vegetation on the Custer Gallatin National Forest. Most of these are native and exist at relatively low population or intensity levels that do not cause notable impacts or have limited localized effects. Insects and diseases can reduce tree growth or result in mortality of specific species or size classes. A few, such as bark beetles can have a more substantial effect as small groups of trees or entire hillsides can be killed in one year. Overtime these agents can change forest compositions and structure. Maps A1.6 to A1.10 in Appendix A display cumulative infestations for insects of concern from 2000 to 2015 by analysis area. Existing conditions are described for the following agents:

- Bark beetles and secondary beetles
- Defoliators
- Root diseases
- White pine blister rust
- Other insects and diseases

### **Bark Beetles and Secondary Beetles**

Bark beetles are the most common biotic agent in terms of trees killed on the Custer Gallatin National Forest. The bark beetles of most importance are mountain pine beetle, pine engraver beetle, and Douglas-fir beetle in the analysis areas where the hosts occur. No hosts for the Douglas-fir beetle occur on the pine savanna unit. Pine engraver beetles are more common on the pine savanna unit and generally see increased infestations during drought periods, areas with untreated slash or in post fire areas. Others such as spruce beetle, western balsam bark beetle, as well as secondary beetles play a lesser role.

#### *Pine engraver beetle*

Pine engraver beetles are relatively non-aggressive beetles that take advantage of host material (ponderosa pine and lodgepole pine) available to adults emerging from overwintering sites. Colonizing such material in early spring often produces another generation of beetles that frequently attack and kill

trees in mid-summer. Most of the pine engravers locally are *Ips pini*, *Ips calligraphus* (six-spined ips), and *Ips emarginatus* (emarginate ips) have also been detected.

Most pine engraver (*Ips spp*) problems are associated with disturbances such as windthrow and snow breakage, drought in spring and early summer, logging, fires, road construction, housing development or other human activities. Pine slash or weakened trees created by these disturbances attract beetles and provide ideal conditions for population buildup and subsequent tree killing.

Pine engraver beetle colonization of fire-injured trees is common on the pine savanna unit. Multiple studies have found that fire-injured trees create a “pulse” event that increases suitable habitat for bark beetles and that the majority of mortality occurs within 2 years following wildfire with a slight level of mortality occurring the 3<sup>rd</sup> post-fire year (Egan and Jackson, 2013). It is rare that populations of pine engraver or mountain pine will buildup in fire-injured trees and progress into nearby undamaged vegetation; however, this is possible under suitable environmental conditions such as protracted drought periods (ibid). Due to the minor detection of pine engraver beetle and the lesser role these beetle have on the montane unit it will only be displayed for the pine savanna unit below.

### *Mountain pine beetle*

Mountain pine beetle (*Dendroctonus ponderosae*) is a native bark beetle which attacks all species of pine and is capable of causing widespread tree mortality. Each bark beetle species exhibits a preference for trees of a certain size (Fettig and Hilszcanski 2015). Mountain pine beetle is generally attracted to the largest trees available (Preisler and Mitchell 1993). Tree death is caused by the feeding of larvae which girdle the cambium, aided by blue-stain fungi (Amman and Logan 1998). Mountain pine beetle prefers dense, shady stands because the microclimate is conducive to survival and communication, and trees are less vigorous (Bartos and Amman 1989; Preisler and Mitchell 1993). Most bark beetle species have a preference for larger trees often with declining radial growth, growing in high density stands with a high percentage of host type (Fettig and Hilszcanski 2015). Typically an outbreak continues until the beetle runs out of host (food) or weather ceases to be conducive, although parasites and predators are also important regulating factors especially when populations are at endemic levels (Amman and Cole 1983). Weather that regulates mountain pine beetle includes extreme cold for extended periods in the winter, late spring or early fall frost, and wet springs/summers (ibid). Abiotic factors including temperature, moisture, and physiographic site conditions such as soils and elevation may also influence tree vigor and stand susceptibility (Six and Bracewell 2015). Frequency of outbreaks generally ranges from 20 to 40 years (Cole and Amman 1980); however, outbreak periodicity is strongly influenced by forest stand conditions. Beetle infestation can result in more open canopies that provide regeneration opportunities for shade intolerant trees, and/or promote the growth of shade-tolerant understory trees.

Mountain pine beetle outbreaks have occurred in the northern Rockies for thousands of years; bark beetles have been found in lake cores indicating their presence at least 8,000 years before present (Brunelle et al. 2008). Most recently a wide-scale outbreak occurred across the Helena National Forest, Lewis and Clark National Forest, and the Beaverhead Deerlodge National Forest from 2006 to 2011. These outbreaks were much more extensive and intensive in mortality than that experienced on the Custer Gallatin National Forest. Several interrelated factors contributed to the conditions that fueled these outbreaks:

- The homogeneity and extent of susceptible forests is created by several factors, including:
  - ♦ Natural fire (which would likely have created a more heterogeneous mosaic of age classes, species, and density) was largely suppressed since the early 1900s;

- ◆ Large stand-replacing fires in the late 1800s and to a lesser extent harvest practices at the turn of the 20th century created an abundance of early seral forests that grew into susceptible even-aged mature forests; and
- ◆ The small extent of modern harvest did little to break up the age class and density homogeneity.
- The climate trends over the last century which included a cool and moist period conducive to the establishment and rapid growth of dense forests and fire exclusion, followed by a shift to warm and dry conditions in recent decades that stressed established forests and favored insect survival.

Infestation varied by analysis areas based on composition and topographical isolation. Analysis areas containing a higher proportion of mature, dense, lodgepole pine and whitebark pine cover types sustained more infestation than those with more diversity. Although the recent outbreak has subsided, mountain pine beetle has always been and will continue to be present on the Custer Gallatin National Forest causing some level of observable tree mortality. Following are graphs by individual analysis areas and the larger montane and pine savanna units depicting recent bark beetle infestation by year. The other category includes the five needle pines; whitebark pine, and limber pine.

#### **Madison, Henrys Lake, Gallatin, Absaroka, and Beartooth Mountains**

Host species present in this landscape are lodgepole pine and whitebark pine with lesser amounts of limber pine and ponderosa pine. From 2003 to 2014 high infestation acreage was detected from 2003 to 2014, with a peak of about 350,000 acres in 2009. Except for a small increase in whitebark pine in 2012, the trend has been declining. In 2015 very low levels were detected. Total infestation acreage in the reporting period was about 860,000 acres. About 53 percent of this was in lodgepole pine, 47 percent in whitebark pine/limber pine and less than 1 percent in ponderosa pine.

#### **Bridger, Bangtail, and Crazy Mountains**

Lodgepole pine, whitebark pine, limber pine, and ponderosa pine are the host species present. Lodgepole pine has the greatest extent of acreage with white bark pine less than half. Ponderosa pine and limber pine are both minor components. Infestation levels were highest from 2006 to 2012, with a peak of about 112,000 acres. Lodgepole pine has had around 180,000 acres impacted in this time period. In 2013 the trend continued to decline with very low levels detected in 2015.

#### **Pryor Mountains**

Lodgepole pine, limber pine, and ponderosa pine are the hosts species present in this landscape. Ponderosa pine (2004) and limber pine (2003) both had infestation levels of around 1,000 acres. Limber pine had a gradual increase a few years prior to 2011 with a peak of about 650 acres of infestation. Lodgepole pine had the highest level of infestation in 2011 of about 1,600 acres. Overall in this time period there has been a gradual increasing trend; however, in 2014, all three species infestation levels were detected at very low levels. The highest amount of infestation acreage has been in limber pine.

Collectively these montane units have had about 1.1 million acres detected with mountain pine beetle. Highest levels were detected between 2007 and 2011. Levels in lodgepole pine peaked in 2009 with a downward trend since. In whitebark pine and limber pine, levels peaked in 2009 as well, but there were elevated levels in 2004 and 2011.

### Ashland District

For the surveyed years between 2001 and 2013 mountain pine beetle had a peak infestation in 2004 on about 1,600 acres. Four of the years had between about 200 and 400 acres. The remaining years has less than 100 acres with 2 years where there was no detection. The pine engraver beetle had a peak of 4,300 acres in 2005. Three years had between 100 and 200 years each. All remaining surveyed years had no detections of pine engraver beetles. Both bark beetles have been at relatively low levels on the landscape. Localized areas have experienced higher mortality.

### Sioux District

No big infestation acreage were detected for the surveyed years between 2001 and 2014. All years with detection were less than 300 acres and more commonly around 100 acres. Two periods (2005 and 2014) had no detections. Pine engraver beetle infestations had a peak of about 2,000 acres in 2003 followed in 2005 with around 900 acres. All other surveyed years with detection had less than 200 acres. Both bark beetles have been at relatively low levels on the landscape. Localized areas have experienced higher mortality.

Combined these two districts make up the pine savanna unit. Three moderately small peaks of infestations occurred in 2003, 2004, and 2005. All other surveyed years that had detected bark beetle infestations were at levels less than 1000 acres. Peaks are generally correlated to severe drought conditions. While geographically widespread, mortality generally is isolated to areas with dense stand conditions and marginal, dry growing environments. Pine engraver beetle mortality post wildfire moderate and high intensity areas and can result in reducing or eliminating a seed source to naturally regenerate the area (Egan and Jackson, 2013).

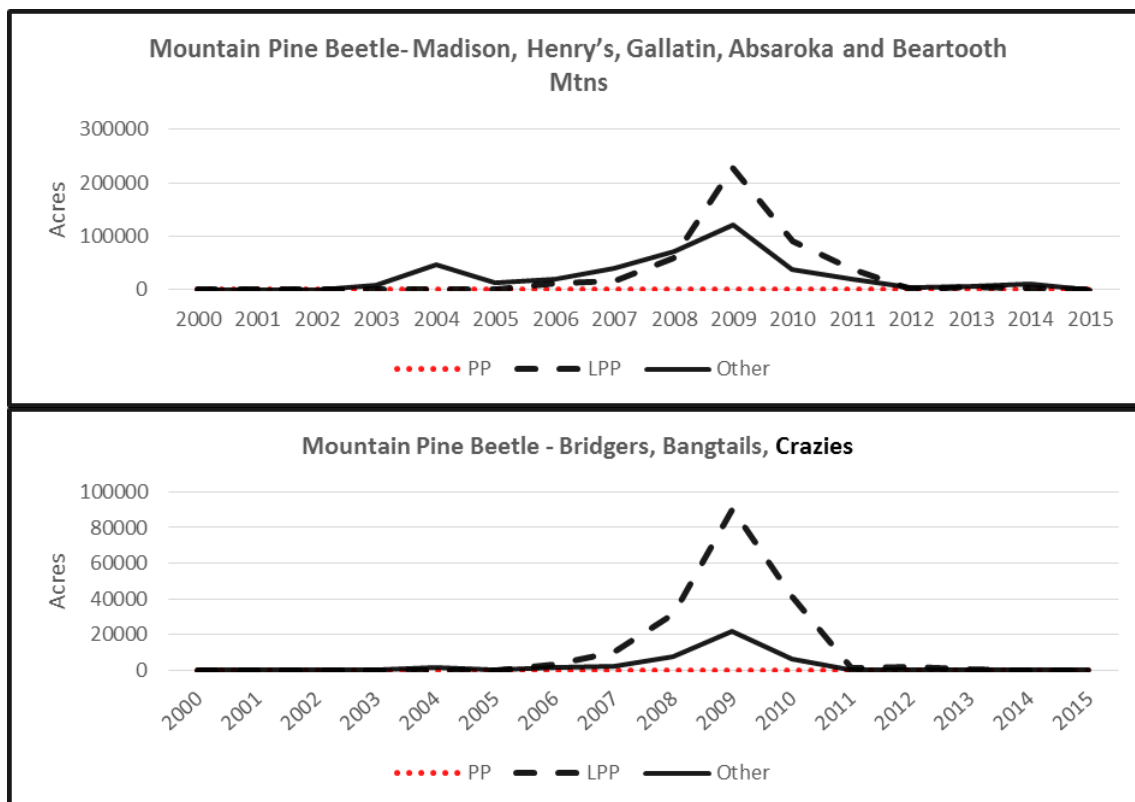


Figure 52. Acres of mountain pine beetle infestations by species from 2000 to 2015, USDA R1-FHP Aerial Detection Surveys



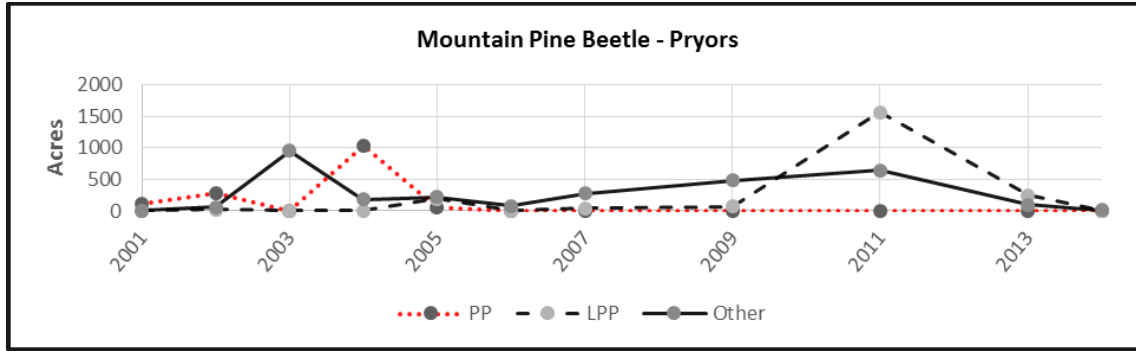


Figure 53. Acres and trend of mountain pine beetle infestations by species from 2001 to 2014, USDA R1-FHP Aerial Detection Surveys

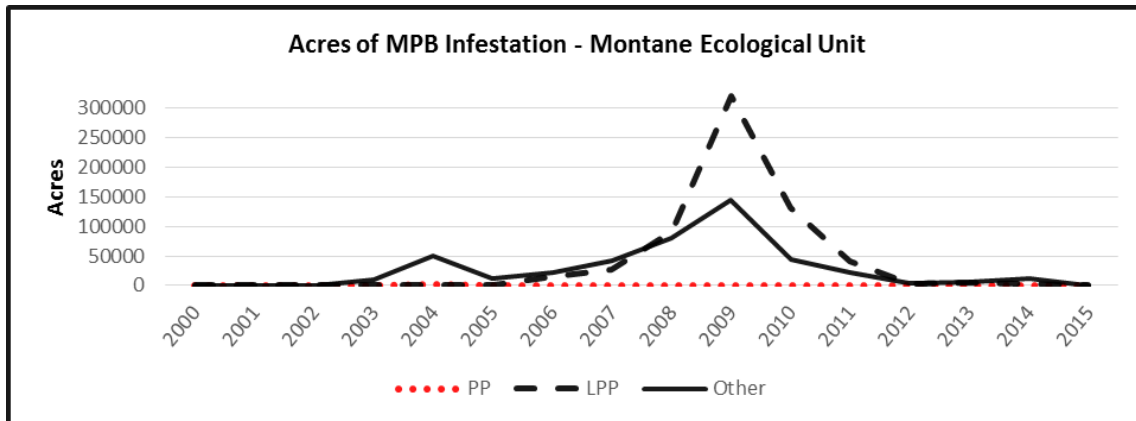


Figure 54. Acres of mountain pine beetle infestations by species from 2000 to 2015, USDA R1-FHP Aerial Detection Surveys

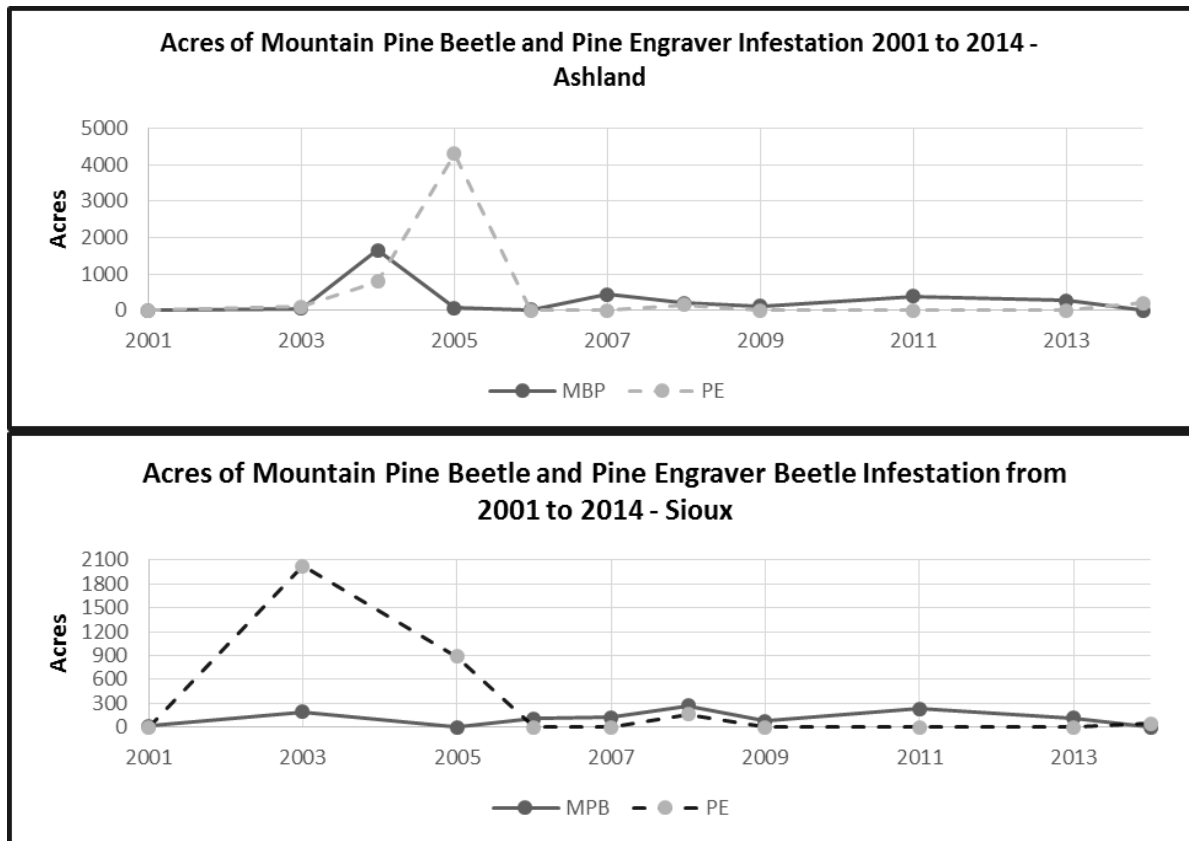


Figure 55. Acres of mountain pine beetle infestations by species from 2001 to 2014, USDA R1-FHP Aerial Detection Surveys

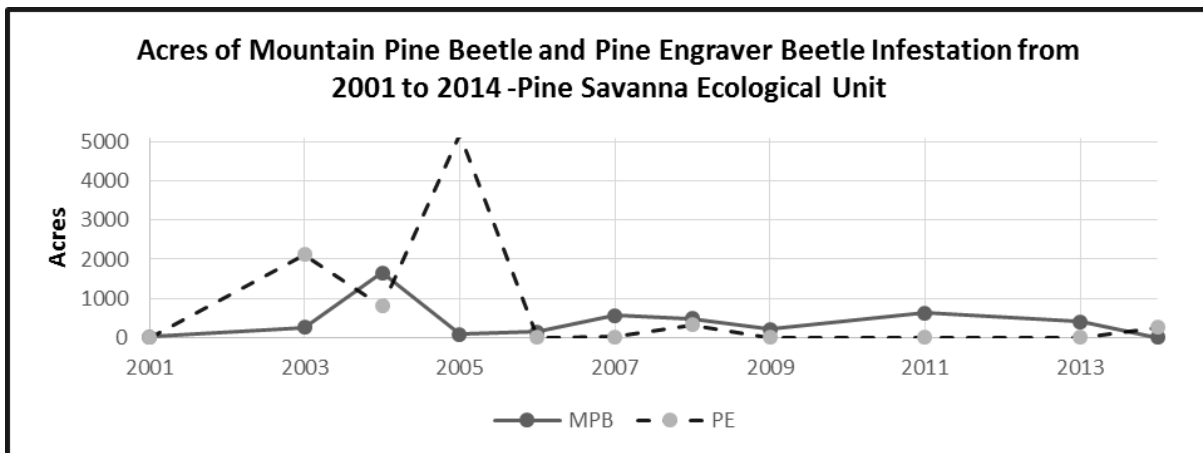


Figure 56. Mountain pine beetle and pine engraver beetle infestation 2001 to 2014 by ecological unit (USDA, R1-FHP Aerial Detection Surveys)

The level of mortality on infested acres varies depending on host conditions; in some areas, only a few trees were killed, while in others several trees were killed. In an effort to understand the intensity of mortality the R1 forest health protection group in 2016 cumulatively mapped tree mortality from the 1999 to 2015 aerial detection surveys into three categories of low (less than 10 trees per acre), moderate (10 to 30 trees per acre), and high (more than 30 trees per acre) intensity. Some of the land

units were not surveyed every year and therefore the data has gaps and should only be viewed as general trends of mortality.

Figure 79 to Figure 83 in Appendix A contain these maps by analysis area. These maps indicate the following:

- Madison, Henrys Lake, Gallatin, Absaroka, and Beartooth Mountains – Predominately low intensity on the Beartooths with localized areas of moderate and high. The Gallatin and Madison areas have more extensive areas of low and moderate. The far north east corner and the central portion of the Madison area has experienced the largest area of high and moderate intensity.
- Bridger, Bangtails, Crazies – Predominately has experienced low and moderate levels of mortality. Bridgers have the largest areas of high mortality with concentrated areas in the west central and south west. The western side of the Bridger's has experienced extensive moderate mortality. The Bangtails have localized areas of high mortality and small areas of moderate mortality. Concentrated areas of moderate intensity occur in the north east and south east of the Crazies with scattered localized high mortality areas.
- Pryors – Predominately low intensity with scattered small areas of moderate/high.
- Ashland and Sioux – Predominantly small areas of low intensity with a few localized moderate intensity areas.

At the local scale, the outbreaks experienced on the Custer Gallatin National Forest was a natural disturbance influenced by anthropogenic factors. At the broader scale, this was part of an outbreak that has affected much of the western U.S. and Canada and studies have shown that some aspects have been unprecedented in terms of extent and elevations and latitudes impacted. Although the outbreaks on the Custer Gallatin National Forest were much smaller in scale than other areas in the east side of the northern region, the areas that have experienced the highest mortality may influence ecosystems and ecosystem services for decades to come, including impacts to ecosystem function as well as human uses such as recreation. The mountain pine beetle outbreak has impacted whitebark pine, a candidate species under the Endangered Species Act, by killing important seed producing trees. The influences of this are discussed in the Plant Distribution – Presence of Individual Species of Interest section.

### *Douglas-fir beetle*

Douglas-fir only occurs on the montane unit. Douglas-fir beetle is the most destructive bark beetle of Douglas-fir in the northern Rocky Mountains. Normally small groups of trees are killed, but during outbreaks groups of up to 100 trees are not uncommon. Outbreaks generally last 2 to 4 years but could be prolonged during drought periods (Kegley 2011). Like the mountain pine beetle, they feed under the bark of the tree (phloem) and can girdle the tree and result in mortality. Although short-lived, epidemics may devastate susceptible stands before subsiding (ibid).

Weather-related phenomena like windthrow, and snow breakage stand disturbances typically can result in the onset of a Douglas-fir beetle outbreak. Defoliation and fire scorch can weaken and trigger and outbreak as well. Douglas-fir beetles are attracted to down trees and logs. Beetles attracted to this material can build high populations in short time periods. Generations produced from this material can attack susceptible green trees in surrounding stands. The likelihood of infestations developing is related to the proportion of the susceptible Douglas-fir and overall stand density. Generally mature or over mature, large diameter Douglas-fir in densely stocked stands are susceptible. However, young smaller diameter densely stocked stands may be susceptible. The higher the proportion of trees that is

susceptible the higher the hazard for Douglas-fir beetle attack. Timely salvage of down, damaged or weakened trees is the primary means of preventing outbreaks (Gibson, 2008).

Following are graphs by individual analysis areas and the larger montane unit depicting recent Douglas-fir beetle infestation by year.

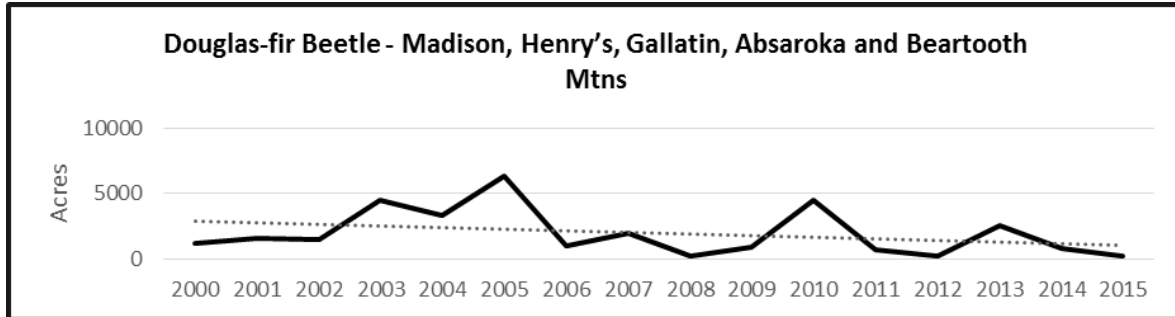


Figure 57. Acres and trend of Douglas-fir beetle infestations from 2000 to 2015, USDA R1-FHP Aerial Detection Surveys

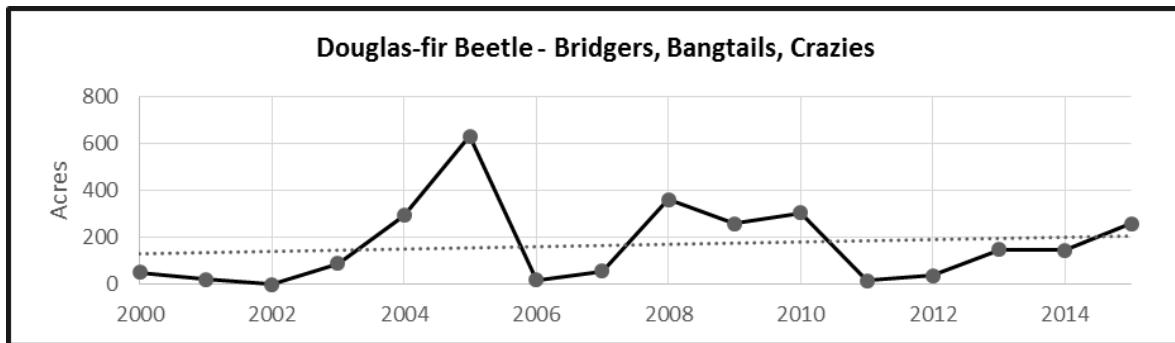


Figure 58. Acres and trend of Douglas-fir beetle infestations from 2000 to 2015, USDA R1-FHP Aerial Detection Surveys

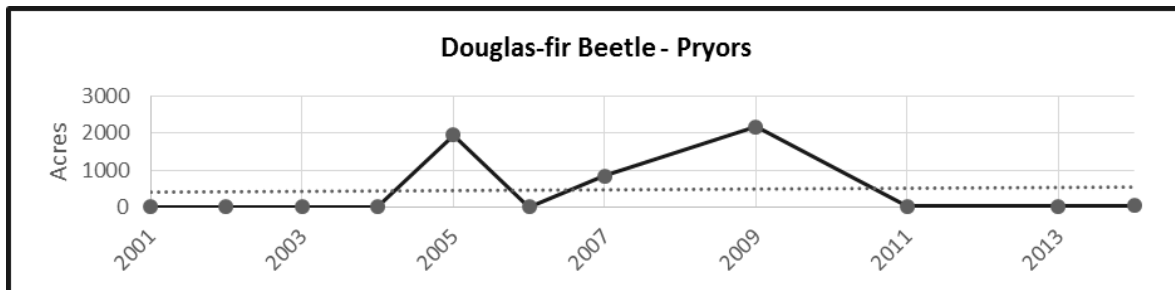
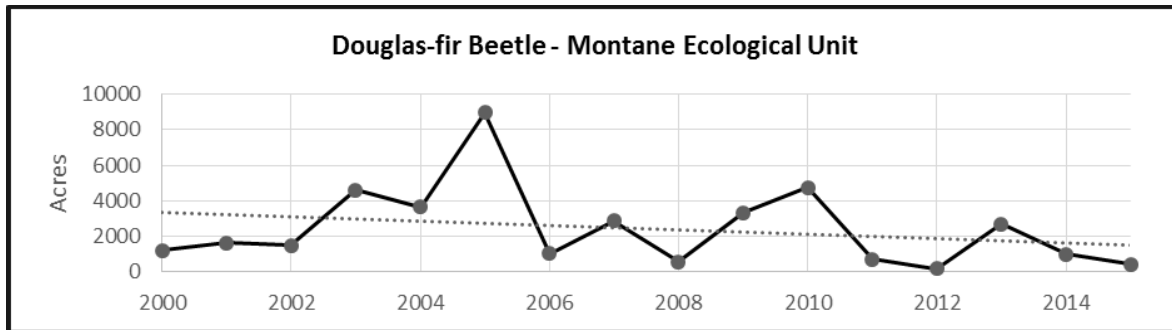


Figure 59. Acres and trend of Douglas-fir beetle infestations from 2001 to 2014, USDA R1-FHP Aerial Detection Surveys



**Figure 60. Acres and trend of Douglas-fir beetle infestations from 2000 to 2015, USDA R1-FHP Aerial Detection Surveys**

#### **Madison, Henrys Lake, Gallatin, Absaroka, and Beartooth Mountains**

For the reporting periods, the highest infestation levels occurred on about 6,400 acres in 2005. There were four additional elevated levels: 2003 – 4,500 acres, 2007 – 2,000 acres, 2010 – 4,455 acres, and 2013 – 2,500 acres. Total infestation acreage in the reporting period was about 31,000 acres. The overall trend in the 15 year period is downward. The second lowest amount was detected in 2015 (approximately 180 acres).

#### **Bridger, Bangtail, and Crazy Mountains**

Like the Madison, Henrys Lake, Gallatin, Absaroka, and Beartooth Mountains, 2005 had the highest acreage reported (600 acres). Two additional elevated levels were detected in 2008 and 2010 both less than 400 acres. The overall trend of infestation appears to be on a slight upward trend.

#### **Pryor Mountains**

This land unit is showing a slight increase in trend of infestation. Two peaks of infestation occurred in 2005 and 2009, both around 2,000 acres. In 2015, infestation levels were low detected on 30 acres.

Collectively, in the 15 year reporting period the montane unit has had about 39,000 acres detected with Douglas-fir beetle. Highest peak levels were detected in 2003, 2005, 2007, 2010, and 2013 with an overall downward trend. Douglas-fir beetle has been at endemic levels across the montane unit on the Custer Gallatin National Forest. Spikes in infestation levels can be attributed to fire events and/or drought weakened trees. Infestation on large diameter trees can be associated with stands that have high defoliation levels from the western spruce budworm.

#### *Other bark beetles*

Other bark beetles that have potential to impact forests on the Custer Gallatin National Forest and have been detected include:

- Red turpentine beetle is the largest and most widely distributed bark beetle in North America. It is a common pest found on the forest, especially the pine savanna unit. Ponderosa pine is the most common host but it will attack lodgepole pine. Red turpentine beetle is not considered to be a tree killer, but its attacks may indicate that the tree is stressed and at increased risk of dying (Randall, 2010). Outbreaks are generally not extensive or severe and most frequently found in individual trees or in groups of trees in localized areas. Adults are attracted by the odor of tree pitch or resin and primarily attack freshly cut stumps or the bases of trees that are dying. Red turpentine beetle can be destructive in areas disturbed by fire, logging, or stands attacked by other bark beetles.

- Spruce beetles pose the most significant insect threat to Engelmann spruce stands throughout its range. Outbreaks have occurred in the Rocky Mountains since the late 1800s with a new wave of outbreaks starting in the mid-1980s continuing to present (Jenkins et al. 2014). Spruce beetle is limited to Engelmann spruce on the montane units. Spruce beetle epidemics in the Northern Region are infrequent, but they can be devastating to old-growth spruce stands, once underway (Gibson 2008). Spruce beetle outbreaks are often associated with blowdown, stumps, large slash, and occasionally fire weakened trees (Munson 2010). They have a two-year life cycle so assessing infestation levels in downed trees could be important in areas where the buildup of beetle populations and resulting mortality may not be desirable. During outbreaks, if susceptible host material is not available, they will attack and kill standing green trees. Epidemics are most common in overmature stands but may be sustained in immature stands 4 inches in diameter and larger (ibid). Significant mortality can result (60 to 80 percent) in spruce stands which have a high hazard for beetle population development (Gibson 2008). About 1,400 acres from 2000 to 2015 have had spruce beetle infestations. A recent wind event in 2007 created 10,000 acres of blowdown inclusive of spruce dominated areas on the Beartooth Ranger District (ibid). This event resulted in an outbreak that lasted 3 to 4 years with an extensive effort to control and protect large trees in 3 campgrounds (Egan 2013).
- Western balsam bark beetle is the most conspicuous of a complex of agents which are responsible for high amounts of tree mortality in subalpine fir forests across its range (Kegley, 2010). Low populations maintain themselves in trees weakened by old age or root disease, and in windthrow or slash. During periods of drought or other environmental stress, infestations can build up over large areas (ibid). This beetle combined with these other agents have resulted in about 163,000 acres of mortality in a 15 year period that has been declining since a peak in 2007(see Figure 61 below).

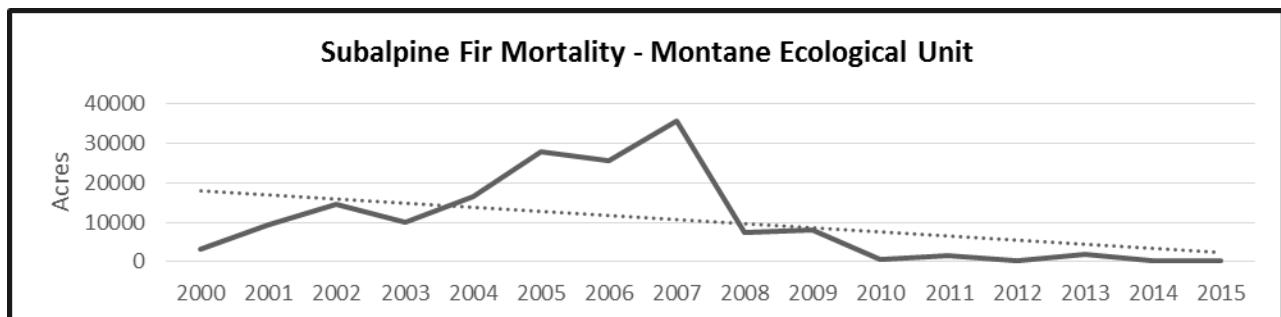


Figure 61. Acres of subalpine fir mortality from 2000 to 2015, USDA R1-FHP Aerial Detection Surveys

#### *Bark beetles interactions with other*

Bark beetles interact with other ecosystem drivers, including climate and fire. These insects are highly sensitive to climate. Drought makes trees more vulnerable to insect attacks. In general, as temperature increases, development rate, initiation of and maintenance of dispersal flights, mating, and oviposition rates are all influenced (Six and Bracewell 2015). The interaction with fuels and fire is complex. The foliar moisture content of needles starts to decrease once a tree dies from bark beetles and has been measured as low 12 percent in red needles as compared to an average of 109 percent for green needles; there is also a corresponding change in the chemical composition of needles as starch, sugar, and fat content decreases (Jolly et al. 2012). These changes appear to influence needle flammability, as red needles ignited more quickly than green needles in a controlled environment (ibid). Schmid et al. (2007) suggest that beetle-killed trees result in increases in dry fuel loads and thereby increase the potential for

severe fires. Fire behavior varies in post-outbreak stands depending upon when they occur; the net result of bark beetle infestation is a substantial change in species composition and a highly altered fuels complex (Jenkins et al. 2008). Early in epidemics there is an increase in the amount of fine surface fuels, while in post-epidemic stands large, dead, woody fuels and live surface fuels dominate (ibid). Passive crown fires may be more likely in post-epidemic stands but active crown fires are less likely after dead needles have fallen due to decreased aerial fuel continuity (ibid). However, there have been local anecdotal accounts of severe wildfire behavior even in the “gray phase”, when dead trees are still standing, which may be in part due to the presence of a living understory beneath the canopy. Once dead trees fall to the forest floor, they create woody debris which can burn with high severity and long duration; the potential for crown fire during this stage would also be dependent upon the remnants of other species in the stand, including understory layers.

### *Secondary beetles*

There are a host of secondary beetles present on the forest. The most notable ones include the round headed and metallic wood borers (families *Cerambycidae* and *Buprestidae*). Generally they do not attack healthy trees but will feed on damaged or dying trees, or downed wood. They are a food source for woodpeckers and are an important process in nutrient cycling. These wood borers are common after wildfires, and can reach outbreak levels.

### **Defoliators**

Defoliators feed on the foliage of trees in their larval stages and disperse as moths, and outbreaks occur in cycles driven by climate and host conditions. Western spruce budworm is the primary defoliator on the Custer Gallatin National Forest. No hosts for western spruce budworm occur on the pine savanna unit, however other defoliators are present but have not had big impacts (pine tussock moth and pine sawfly).

### *Western spruce budworm*

Western spruce budworm (*Choristoneura occidentalis*) is the most widely distributed and destructive defoliator in the western United States (Bulaon, Sturdevant, 2006). Budworm plays a critical role in forest nutrient recycling and regulating stand composition and structure. Budworm eats the needles of Douglas-fir, subalpine fir, and spruce, though other species (pines) may be defoliated during epidemics. When populations of western spruce budworm reach epidemic proportions, they can cause a reduction in growth, top kill, tree mortality, and mortality in regenerating trees (ibid). Cones and seeds can also be destroyed (Pederson et al. 2011, Fellin and Dewey 1982). Western spruce budworm outbreaks tend to last long and cause less direct tree mortality because the worms preferentially feed on current year foliage.

Larvae disperse by moving up and out from their egg masses and spin silken thread to “balloon” on the wind to a new host. The upper story provides a food source and refuge from predation and parasitism while the lower canopy layers intercept budworm spinning from above and provide sanctuary from predators on the forest floor (Pederson et al. 2011). Because of this habitat conducive to destructive infestations tend to be dense (high basal area) with a high host component and with multiple canopy layers which intercept the ballooning larvae.

Budworm outbreaks are influenced by climate, weather, parasites, and predators but depends on suitable habitat. Warm dry climates and stands on dryer aspects are more susceptible (Brookes, et al. 1987). Mortality is usually concentrated in smaller, suppressed pole and sapling size trees (Pederson et

al. 2011). However following drought periods, large stressed trees can be killed in combination with the Douglas-fir beetle (Kegley 2011).

From 2000 to 2015, the montane unit has experienced western spruce budworm outbreaks in all but the first 2 years. Three peaks have occurred in 2006, 2009, and 2012 all over 100,000 acres. The highest infested acreage occurred in 2009 at about 200,000 acres with the total infestation acres at about 1 million acres. Below are graphs and descriptions of infested acres of western spruce budworm by the individual montane analysis areas.

### **Madison, Henrys Lake, Gallatin, Absaroka, and Beartooth Mountains**

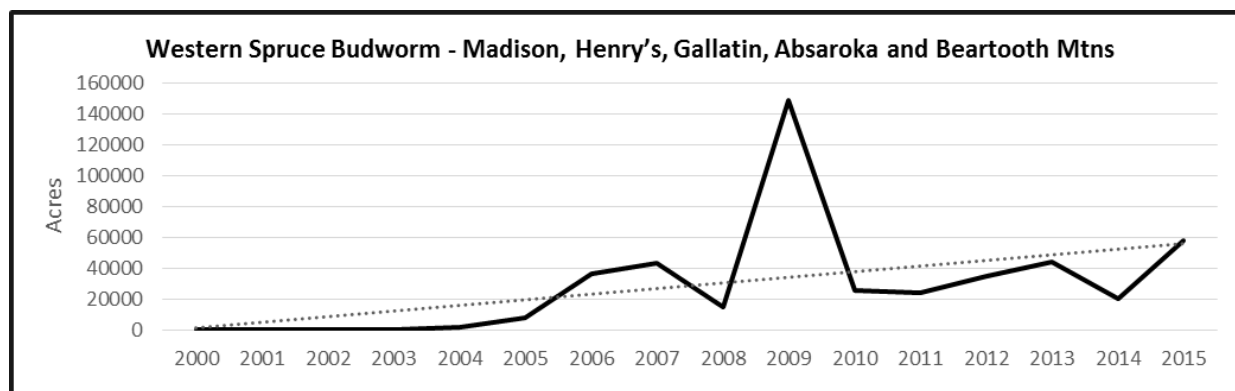
First detection was in 2004 with a spike in 2009 on about 149,000 acres. Three additional years had around 40,000 acres each. The 2015 survey indicates another increase with defoliation on about 58,000 acres. An increasing trend has occurred the last 12 years across a total of about 459,000 acres.

### **Bridger, Bangtail, and Crazy Mountains**

Since 2002, there has been an increasing trend. Total acres detected with defoliation was around 564,000 acres. Western spruce budworm defoliation was first detected in 2002 and spiked in 2009 on about 149,000 acres. Two other years (2006 and 2012) had levels around 100,000 acres. The survey in 2015 indicated another increase in acres.

### **Pryor Mountains**

Initial Western spruce budworm outbreaks have generally moved from the north east to the west across the Custer Gallatin National Forest. The Pryors had no defoliation detected until 2009 and only on about 500 acres. No surveys were done in 2008, 2010, 2012, and 2015. Seventy acres were detected with defoliation in 2014. In 2015, adjacent landowners reported large outbreaks (1,000+ acres) on private land adjacent to the forest. With this amount of acreage impacted, surveys in 2016 on National Forest System lands are expected to show increased acres of infestation.



**Figure 62. Acres and trend of WSBW infestations from 2000 to 2015, USDA R1-FHP Aerial Detection Surveys**



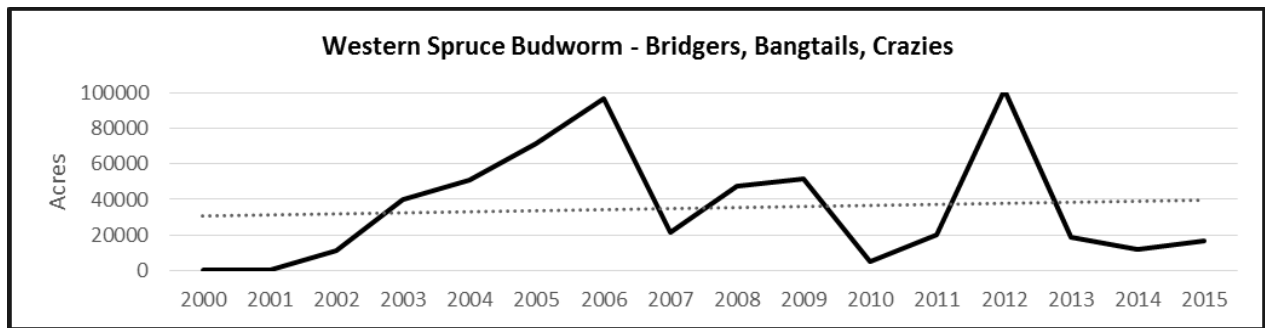


Figure 63. Acres and trend of WSBW infestations from 2000 to 2015, USDA R1-FHP Aerial Detection Surveys

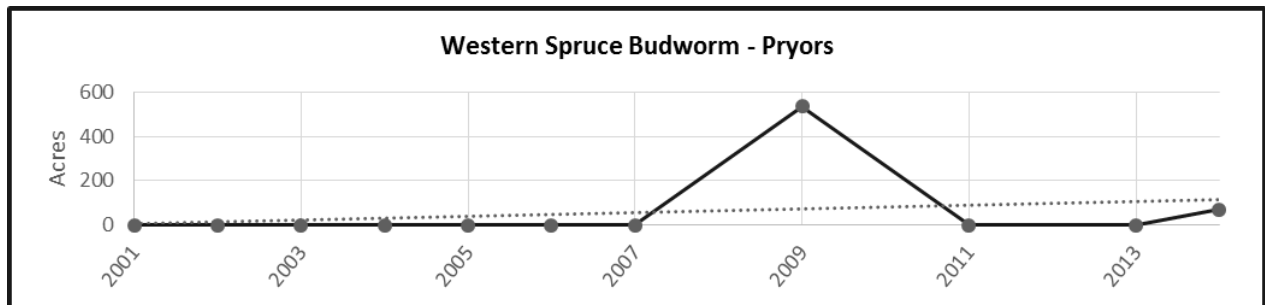


Figure 64. Acres and trend of WSBW infestations from 2001 to 2014, USDA R1-FHP Aerial Detection Surveys

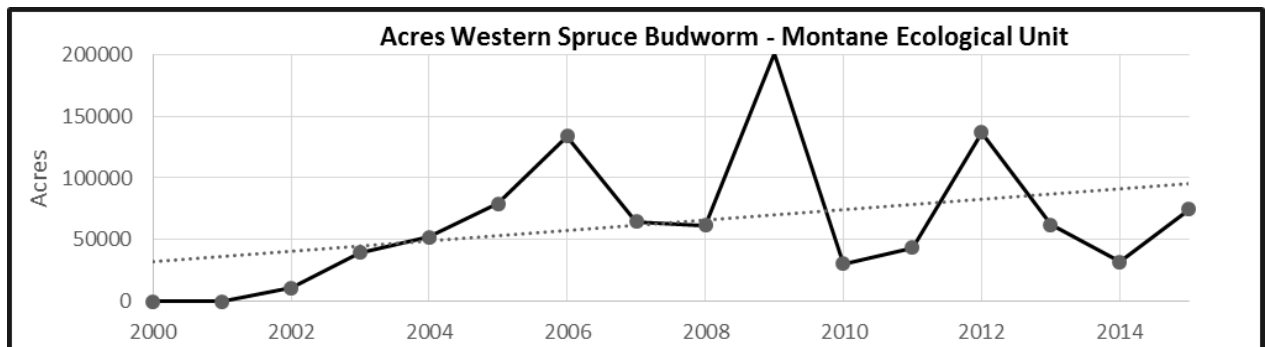


Figure 65. Acres and trend of WSBW infestations from 2000 to 2015, USDA R1-FHP Aerial Detection Surveys

Although western spruce budworm is a native insect that has co-evolved with western spruce-fir forests, extensive damage and mortality from budworm can occur especially during drought periods and in areas where fire has been suppressed (Sturdevant et al. 2012). As forests become dense with a higher composition of Douglas-fir, they will become more susceptible and outbreaks may become more frequent and severe (Pederson et al. 2011). Good budworm habitat consists of dense, multiple layers of climax host species (ibid). High host crown cover, stand density, and multi canopy layers are the strongest indicators of stand susceptibility to budworm damage (Brookes et al. 1985, 1987). Defoliation has been present and increasing over the last 14 years in large part due to warm, dry weather and a preponderance of dense, layered forests. Declines in acres infested in this period are likely due to wetter springs and summers. Added stress from defoliation can also predispose trees to attack by Douglas-fir beetle.

### *Balsam wooly adelgid*

Balsam wooly adelgid is a nonnative pest that causes branch dieback and can cause tree mortality in subalpine fir. The most obvious indicator of its presence is the white “wool” covered females on the bark of stems and branches of trees during summer months. Balsam wooly adelgid has been observed causing branch dieback and overall stress and direct mortality has not been documented (USDA 2016). Balsam wooly adelgid was first detected in Montana in 2010. Extensive ground surveys were conducted in 2013 throughout the state by Montana Department of Natural Resources and Conservation and the R1 forest health protection program. These surveys found balsam wooly adelgid in 11 counties including Gallatin County on the Custer Gallatin National Forest. In 2014, ADS first recorded balsam wooly adelgid and in 2015 aerial detection surveys found 358 acres with balsam wooly adelgid damage (ibid). Detections will increase as balsam wooly adelgid continues to cause more extensive tree damage within the state.

### Dwarf Mistletoe

Dwarf mistletoes are the most widely dispersed native pathogen in the western United States (Hawksworth et al. 1996). Mistletoes are a parasitic plant that extract water and nutrients from their host. Lodgepole pine is the only known conifer on the Custer Gallatin National Forest impacted by this agent (*Arceuthobium americanum*). Dwarf mistletoe is common on the Custer Gallatin. As an example, on the Beartooth district it is estimated that 28 percent of the lodgepole pine forest type is affected with dwarf mistletoe in 2004 (Hoffman, 2004). Mistletoes reduce growth, wood quality, seed production ability, and life span of the host tree. Severe infections will eventually kill the tree. Infected trees can increase activity of secondary pests (beetles) that often attack and kill the infected trees (Hawksworth et al. 1996). The plant and the broom are important ecosystem components such as for a winter food source and nesting habitat for many wildlife species.

Several forces influence their distribution on the landscape with fire being one of the foremost factors in their population dynamics. Generally any fire event that kills their host trees will reduce the population of dwarf mistletoes, at least in the short term (Hoffman, 2004). However, spotty fires can leave infected trees that not only regenerate the stands but can re-infest it (Hawksworth et al. 1996).

### Root Pathogens

Root diseases are pathogens that live in root systems and break down cellulose and lignin. They compromise the uptake of water and nutrients and eventually cause mortality. They are commonly endemic in areas with susceptible hosts and are persistent where present. Older trees and high density stands are at higher risk to some root and butt rots than younger, more open-grown stands. On sites with a root disease-susceptible forest type and climax species, high levels of disease may maintain early stand development because the stands experience waves of mortality as trees grow and healthy roots contact diseased roots allowing the disease to spread; this is not a common phenomenon on the Custer Gallatin.

Root diseases are diseases of the site and do not change drastically from one year to the next. Once established on a site, root disease fungi can be persistent to essentially permanent, living for decades in the root and stumps and killing new trees that seed into the site (Hagle 2010). Root disease-caused mortality is more common west of the Continental Divide. The region currently does not have an assessment of root disease distribution and impact east of the Continental Divide (USDA, 2016). In general, large areas of root disease can be found east of the Divide, but it tends to occur in more discrete patches, rather than being ubiquitous throughout an area. Also, root diseases can be commonly found in riparian areas east of the Continental Divide, often in Engelmann spruce and

subalpine fir (ibid). The most impacting root diseases in the northern region are Armillaria root disease, laminated root rot, Heterobasidion root disease, schweinitzii root and butt rot, and to a lesser extent tomentosus root rot. Tree species most susceptible to root disease on the Custer Gallatin National Forest are Douglas-fir and subalpine fir, with Engelmann spruce being moderately susceptible and pines generally less susceptible.

No root disease pockets were detected on the Custer Gallatin during the 2000 to 2015 aerial detection surveys. This does not mean it is not present. Low levels are present in diffuse patterns and are undetected due to the subtle nature of expression. Tomentosus (*Inonotus tomentosus*) has been detected in spruce within campgrounds on the Custer Gallatin National Forest and has the greatest potential for concern (Egan Steed 2010). Locations of campgrounds are typically in or nearby riparian areas containing large spruce. Tomentosus presents a safety concern as it rots the roots and butts of trees, especially old Engelmann spruce, leading to increased windthrow.

#### *Root Pathogen and Insect Interaction*

Bark beetles are able to detect trees which are damaged by root disease long before they are visibly weakened. Larger declining trees are often attacked and killed by bark beetles. Douglas-fir beetles, fir engraver beetles and western balsam bark beetles may utilize root disease weakened trees to maintain endemic population levels (Hagle, 2010).

### **White Pine Blister Rust**

White pine blister rust (*Cronartium ribicola*) is a nonnative, introduced disease that entered the United States from Europe early in the 20th century. By the 1940s widespread infection was noted throughout the western United States. It infects all five-needled pines, including limber and whitebark pine that occur on the montane unit of the Custer Gallatin National Forest. This disease has a complicated life cycle composed of five spore types alternating between two hosts. In addition to five needled pines, it requires an alternate host such as currant plants, *Ribes spp* (Tomback et al. 2001). The disease creates cankers on branches and the stem, usually eventually girdling and killing it although a small proportion of trees with resistance traits can survive indefinitely. Although mortality does result, it is a slow process. Of greater importance may be the mortality of cone-producing branches which reduces the reproductive potential of whitebark and limber pines, which is especially critical in areas that are disturbed by fire.

Successional pathways have been altered because species not susceptible to the disease are favored. Many five-needled pine stands have become dominated by snags, with only a few seed-bearing survivors that possess one or more resistance traits. However, in many areas, there are abundant seedlings and saplings.

Blister rust is wide-spread and continuing to increase in incidence and severity. Infection rates in monitored Greater Yellowstone Area plots average 20 to 30 percent and range from 0 percent to 84 percent (Greater Yellowstone Whitebark Pine Monitoring Working Group, 2016). Whitebark pine is highly vulnerable to infection by blister rust, however approximately 26 percent of the Greater Yellowstone Area population showing genetic resistance to the rust (ibid).

#### *Bark Beetle and Climate Interactions with Blister Rust*

Because mountain pine beetle may be killing trees with natural blister rust resistance, there is a need to implement restoration strategies to reduce losses and save at least some of the whitebark pine from beetle attack. A warmer and moister weather pattern may also favor white pine blister rust by producing frequent “wave years” of conditions that promote massive numbers of infections (Schwandt,

2006). Warmer weather may also favor mountain pine beetle, and recent outbreaks have been more intense due to several mild winters that allowed more of the bark beetle population to survive (ibid).

See additional information in Plant Distribution – Species of Special Interest and Climate Change for additional information on whitebark pine limber pine.

### Other Insect and Diseases

There is a host of other insects and pathogens that play a role in the forested ecosystem on the Custer Gallatin National Forest but are not identified as major drivers. Those that may be present but not limited to include: to red ring rot, western gall rust, Comandra and stalactiform blister rusts, pine pitch mass borer, wood wasps, broom rusts, pine shoot blight, gouty pitch midge, terminal weevils, western pine shoot borer, pine tip moths, pine saw flies, pine tussock moth, aphids, Cooley spruce gall adelgid, rhabdocone needle cast, pine needle miners, as well as a host of stem decays, casts, blights, needle scales and cone and seed insects.

### Trend

#### *Historical Conditions*

With the exception of white pine blister rust and balsam woolly adelgid, the insects and pathogens on the Custer Gallatin National Forest are native and have co-evolved with their hosts over millennia. Through selective killing or reducing growth of trees, they influence structure and composition which affects other processes such as fire. They benefit plants and animals that utilize dead or modified wood, or feed on insects or pathogens. These agents have a role in maintaining soil fertility. Climate and weather play a major role in controlling insects, as does availability and quality of food and breeding habitat. Historically, insect populations would periodically build to high levels under favorable climatic and host conditions. Frequency of epidemics varies by species and locality. Cool climate conditions, such as those that predominated from the 1940s through the 1970s, were not conducive to outbreaks. The current warm/dry cycle correlates with the increased extent of outbreaks since the 1980's. Human actions such as fire suppression, past logging practices, and land development in conjunction with succession influence vegetation which influences the population or intensity of insects and diseases. Higher stand densities increase stress and competition for resources, which renders trees less able to resist insect and diseases (Fettig et al. 2007).

Historical trends for the montane and pine savanna units are summarized from aerial detection survey data in Figure 66 and Figure 67 for the insects of interest. The period for the montane is 1962 to 1999 and for the pine savanna 1971 to 1999 for the years that aerial detections were conducted (see Figure 66 and Figure 67 below).

- Montane Ecological Unit: Douglas-fir beetle had an outbreak on about 21,000 acres in 1964. Three other smaller outbreaks between 2,700 and 3,900 acres per year occurred in 1992, 1994, and 1988. All other years, Douglas-fir beetle has been at low levels. Mountain pine beetle was detected in all but 5 years. Cumulatively, mountain pine beetle mortality was detected across and estimated 3,522,670 acres from 1975 to 1984, all other years mountain pine beetle detection was less than 3,000 acres per year. Western spruce budworm has been present with regular outbreak cycles. There have been 4 peak levels: 1964 (approximately 304,000 acres), 1977 (approximately 203,000 acres), 1980 (approximately 240,500 acres), and 1984 (approximately 957,700 acres). From 1995 to 1999 no detections were documented.

- Spruce budworm has been detected with elevated outbreak cycles since 1962. Douglas-fir beetle has a slight upward trend in average acres detected per year in 2000 to 2015 as compared to 1962 to 1999 for the years surveyed. Acres of mountain pine beetle detection during the 2007 to 2011 was about 1/3 of that in the 1975 to 1984 outbreak. Not considering the outbreak years, MPB average detection acres per year is increasing in 2000 to 2015 as compared to 1962 to 1999.
- Pine Savanna Ecological Unit: Hosts for Douglas-fir beetle and spruce budworm are not present. The largest detections of mountain pine beetle occurred in 1981 (approximately 8,400 acres) and in 1985 (approximately 60,400). All other survey years, mountain pine beetle was detected at low levels.
- Discounting 1985 (the highest outbreak year), there is a small increasing trend of average acres per year of bark beetle (mountain pine beetle and pine engraver beetle) detection from 2000 to 2015 as compared to 1971 to 1999 surveyed years.

Historically, mountain pine beetle outbreaks have occurred somewhere in the Northern Region (Montana and northern Idaho) about every 10 to 15 years, most notably in the 1930s on the Beaverhead-Deerlodge National Forest and the 1980s in northwestern Montana. Large scale outbreaks of other bark beetles have been less common and dramatic. Western spruce budworm is known to have chronic outbreaks in the Northern Regions roughly every 20 years driven by climate and cyclic population dynamics. Frequent outbreaks on the Custer Gallatin National Forest are evidenced by deformed “bottle-brush” shaped trees that survived the previous outbreaks.

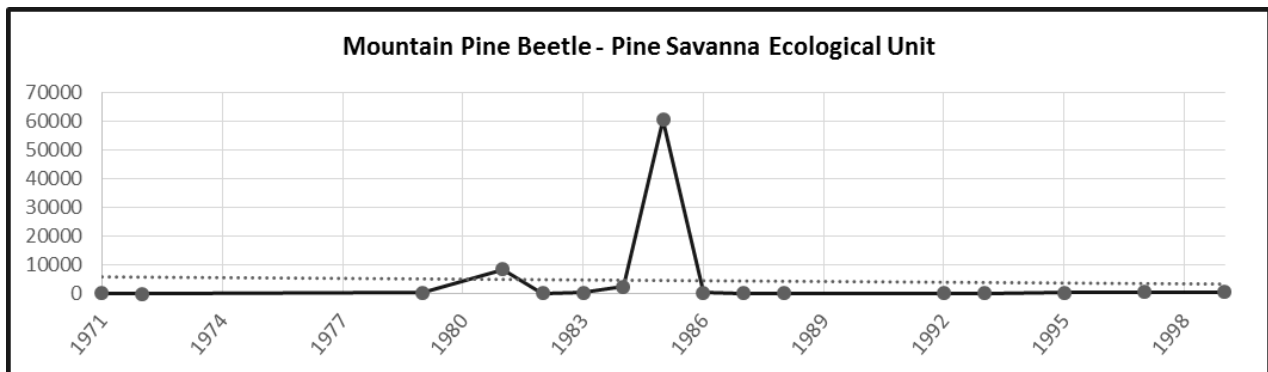


Figure 66. Acres and trend of Mountain Pine beetle infestations from 1971 to 1999, USDA R1-FHP Aerial Detection Surveys

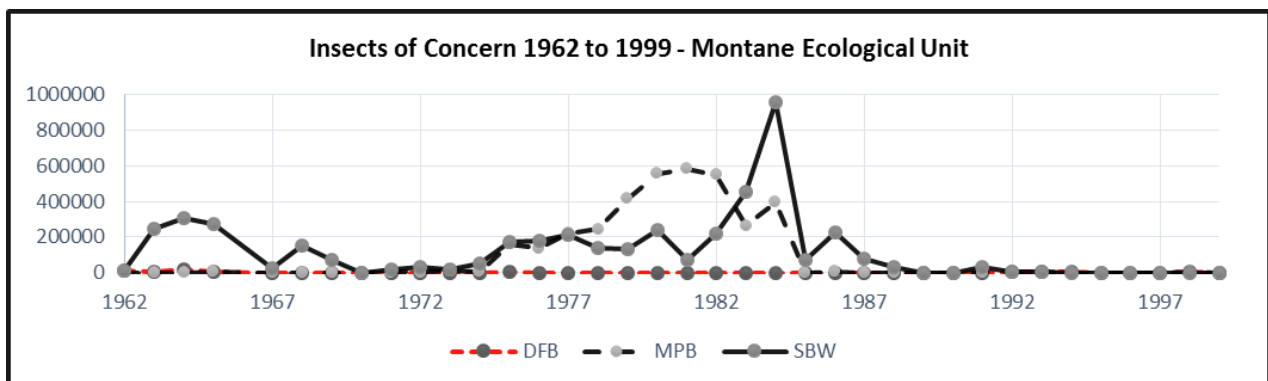


Figure 67. Acres of infestations by insects of interest from 1962 to 1999, USDA R1-FHP Aerial Detection Surveys

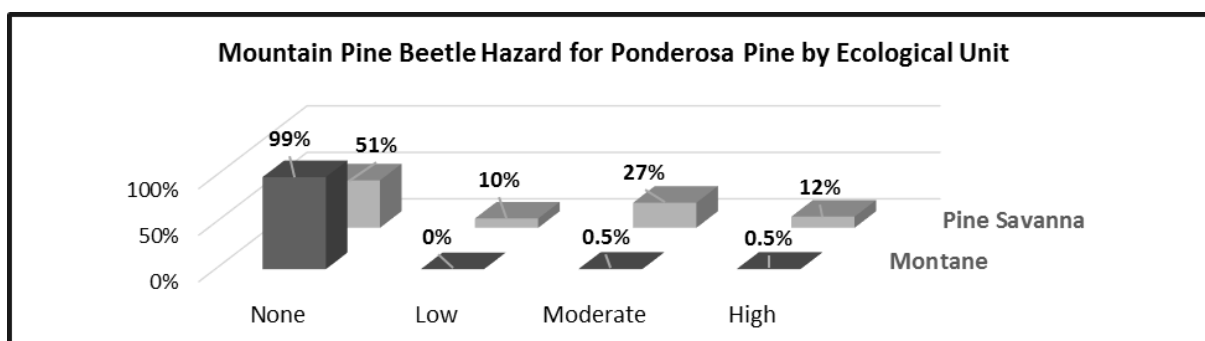
### Expected Future Trend for Insects of Concern – Hazards

Considering the current warm/dry period and anticipated climate trend, the future extent and damage of most insects and pathogens may increase (USDA 2015b). This could be influenced by human activities and availability of susceptible hosts and will have variability and some level of uncertainty (ibid).

However by estimating hazards, trends can be in part predicted. Hazard is synonymous with “susceptibility”, and is defined by forest characteristics suitable for the insect of interest. Whether or not an outbreak occurs, and the severity of damage, also depends on *risk* – or the presence of the insect or pathogen where it can utilize susceptible forests. Regional forest health protection entomologists and inventory specialists have developed hazard rating systems for the species of interest (mountain pine beetle, Douglas-fir beetle, western spruce budworm, and pine engraver beetle) which can be applied to forest inventory and analysis plots (Randall et al. 2011). These hazard ratings evaluate the susceptibility of forests by evaluating the quality of the host and quantity of the food source. The quality and quantity is best characterized by species composition (amount of host) and stand density. These hazard ratings do not predict when or if significant mortality will occur as there has to be not only the susceptible host present, but an insect population and favorable weather conditions. High and moderate hazard areas are more likely to experience significant mortality if insect populations are present and the weather is favorable (ibid).

### Mountain pine beetle

Mountain pine beetle is the most aggressive, persistent, and destructive bark beetle. This beetle attacks the host and feeds on the inner portion of the bark that may result in girdling of the tree. This girdling reduces or eliminates the ability for the tree to transport water and nutrients to the tree, resulting in mortality. Stand conditions conducive to infestations are pine stands that are dense and have a combined pine species component of trees larger than 7 inches in diameter at breast height. Mountain pine beetle hazard is driven by species composition, tree size, and stand density. The quality of ponderosa pine as mountain pine beetle food is best characterized by stand density and phloem thickness (ibid). A pure, well-stocked ponderosa pine stand will be more likely to support a large mountain pine beetle population than a mixed species and/or poorly stocked stand (ibid). About 218,000 acres on the pine savanna unit and 8,100 acres on the montane unit are at moderate to high hazard to mountain pine beetle in ponderosa pine. Ponderosa pine acreage is very limited on the montane unit.



**Figure 68. Mountain pine beetle hazards for ponderosa pine proportion of ecological unit, R1 Summary Database, FIA plots**

Combined bark beetle hazard (pine engraver and mountain pine beetle) for ponderosa pine, limber pine, whitebark pine, and lodgepole pine is displayed in

Figure 69 below. Moderate and high hazard acreage on the pine savanna unit remains about the same for only mountain pine beetle hazard and on the montane unit FIA indicates about 885,000 acres.

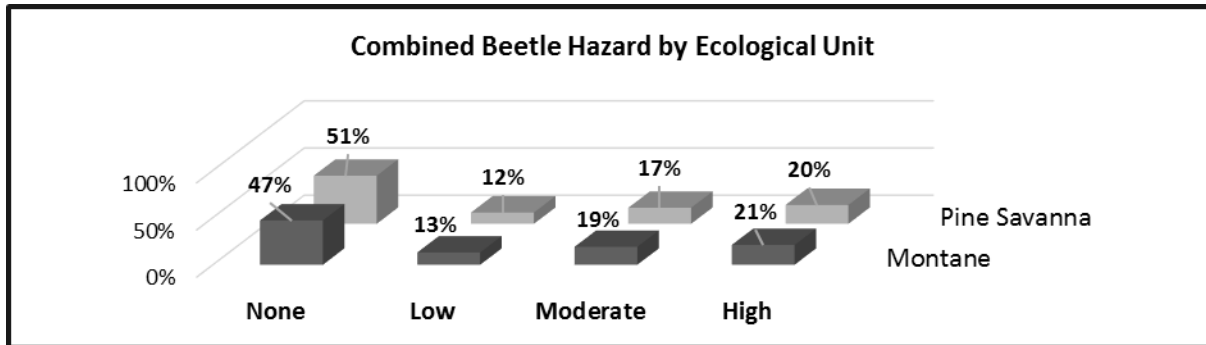


Figure 69. Combined pine beetle hazard by proportion of ecological unit, R1 Summary Database, FIA plots

Hazard to mountain pine beetle in ponderosa pine by analysis area are displayed in the Figure 70 below. Of interest to note is that the analysis areas that have limited ponderosa pine have no or less than 1 percent with a moderate or high hazard. The Sioux and the Ashland district which only contain ponderosa pine have 48 percent and 34 percent respectively in moderate and high hazard. Although there are large areas rated with moderate or high it is interesting to note that from 2001 to 2014 mountain pine beetle infestation extent and intensity have been relatively low (Appendix A Figure 82 and 83).

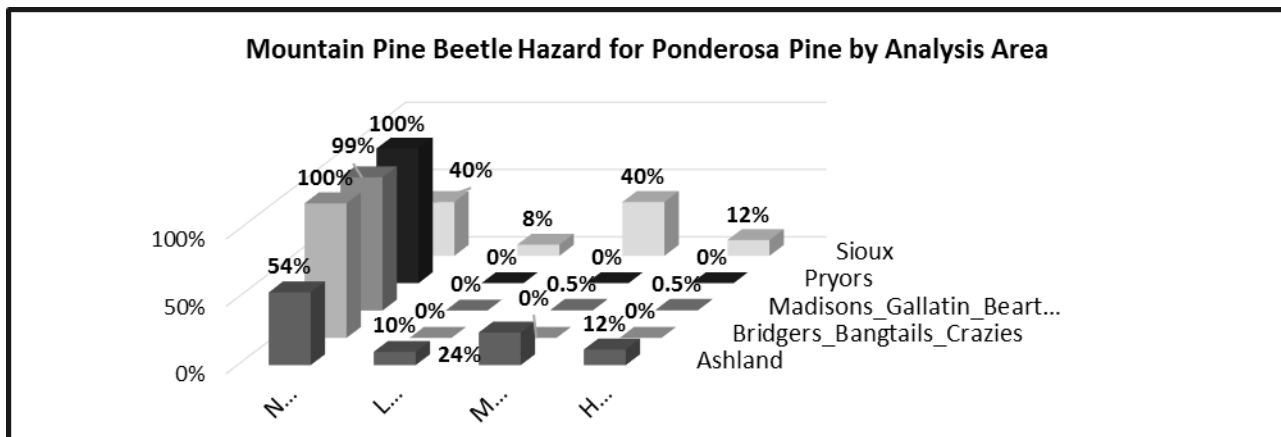


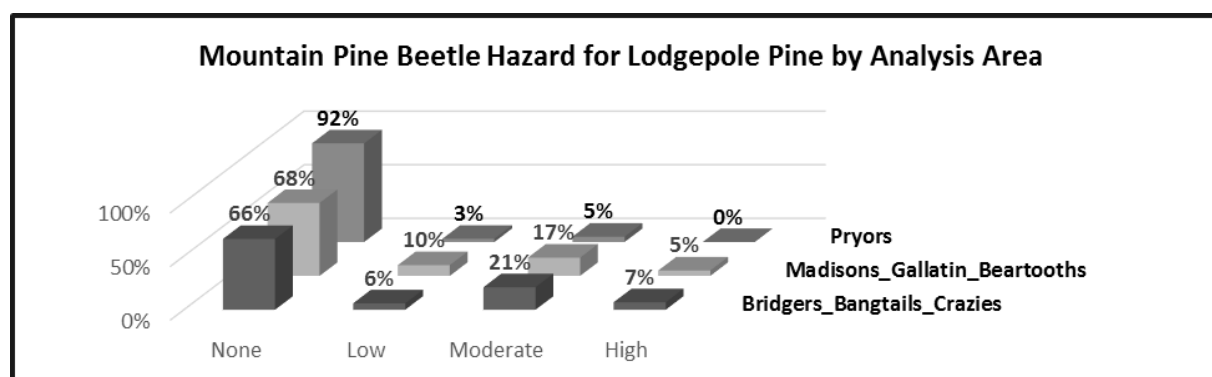
Figure 70. Mountain beetle hazard for ponderosa pine by proportion of analysis area, R1 Summary Database, FIA plots

Lodgepole pine occurs only on the montane unit and is an extensive cover type. Epidemics develop in lodgepole pine stands with well- distributed, large-diameter trees; the hazard rating system uses criteria such as diameter, basal area, species composition, and elevation (Randall et al. 2011). Susceptible stands are dense (at least 100 square feet of basal area per acre) and have a high composition (at least fifty percent of the basal area) of large diameter (at least eight inches diameter) lodgepole pine, although outbreaks may be limited once basal area becomes too high, such as in dense stands of small diameter trees, or if stands are at high elevations (ibid). Nearly 500,000 acres on the montane unit have a moderate to high hazard to mountain pine beetle based on the forest inventory and analysis plots. That is about 50 percent of the total acreage where lodgepole pine is present and 74 percent of the acreage where lodgepole pine occurs that is greater than or equal to 5 inches in diameter. As discussed

above, since 1999 most of the montane units have had predominately low and moderate mortality levels and are still susceptible to mountain pine beetle outbreaks. Those areas that had higher mortality are at a lower hazard today because of the amount of host killed.

**Table 42. Acres of mountain pine beetle with moderate or high hazard by analysis area, R1 Summary Database, FIA plots**

Analysis Area	Acres of Hazard		
	Moderate	High	Total
Pryors	4,100	0	4,100
Madison, Henrys Lake, Gallatin, Absaroka and Beartooth Mtns	341,647	96,909	438,556
Bridgers, Bangtails, Crazies	38,676	14,504	53,180
Total	384,423	111,413	495,836



**Figure 71. Mountain pine beetle hazard for lodgepole pine by proportion of analysis area, R1 Summary Database, FIA plots**

For the majority of the lodgepole pine and whitebark pine acreage on the montane unit there is still the potential for outbreaks in the short term as well as in the ponderosa pine on the pine savanna unit. Limber pine although a less dominant species but important cover type, is expected to sustain mortality and outbreaks on the montane units. For those areas that had concentrated high mortality in recent years (Bangtails and the Madison mountains) outbreaks in the next few decades will be limited until lodgepole pine forests re-establish and grow to maturity.

Mountain pine beetle is an important part of ecosystem function. As long as there are continuous pines of sufficient size and density available and favorable climate conditions occur simultaneously, outbreaks will occur. Actions that mimic the past century's actions could result in future large outbreaks 80 to 100 years from now; allowing for management and natural events that promote heterogeneity in species and age class could reduce that likelihood. While the efficacy of management actions to directly suppress beetle outbreaks has been questioned (Six et al. 2014), a viable long-term preventative solution to uncharacteristic outbreak levels may be to change forest structure and composition to increase resiliency by incorporating sound, appropriate forest management tools such as prescribed fire and timber harvest (Fettig et al. 2014).

Thinning has long been an advocated as a preventative measure to alleviate or reduce the amount of beetle caused tree mortality (Mitchell 1994, Gibson 2004, Fettig et al. 2013). Thinning reduces host availability that supports beetle populations, reduces competition among trees for nutrients, water, and



other resources thereby increasing vigor and affects microclimate decreasing the effectiveness of chemical cues used in host finding, selection and colonization and influencing beetle survival. Thinning from below may optimize the effects of microclimate, inter tree spacing, and tree vigor even if the residual trees are of diameter classes considered more susceptible to attack (Fettig et al. 2013). Studies have shown that thinning from below in mature lodgepole pine to a inter tree spacing of at least 13 feet is effective for mitigating levels of tree mortality attributed to mountain pine beetle.

Thinning in second growth ponderosa pine has been found to have a large impact on beetle caused mortality (Gibson 2004). Thinning has been documented to reduce levels of mortality in ponderosa pine when basal areas were thinned to 45 to 85 square feet per acre (Fettig et al. 2013).

Landscapes tend to become more homogenous as fire is removed because succession will eventually advance all stands to similar communities dominated by shade tolerant species (Keane et al. 2002). Landscape structure (spatial distribution of patches) also changes with fire exclusion as landscapes generally become less fragmented, have lower patch density, and evolve decreased patch diversity, which often results in more contagion, corridors, and large patches (ibid).

A solution for indirect treatments in homogeneous susceptible host landscapes is to change forest structure and composition to increase resiliency (Fettig et al. 2013). Regeneration treatments in small to moderate sized areas will create age and size mosaics within landscapes of homogenous even-aged forests that ultimately reduce impacts by the mountain pine beetle (ibid).

### **Douglas-fir beetle**

Douglas-fir outbreaks tend to occur for longer periods of time over entire landscapes (Hessburg et al. 1994). Stress induced from climate change will likely promote both increased western spruce budworm and Douglas-fir beetle infestations. Douglas-fir has the largest representation of large trees per acre and Douglas-fir beetle has the potential to affect this valuable habitat component (Table 60). Hazard ratings are based upon the average diameter of Douglas-fir, stand basal area, and percent composition of Douglas-fir (Randall et al. 2011). The likelihood of a Douglas-fir beetle infestation developing in a stand is related to the proportion of susceptible Douglas-fir and stand density. The availability of large trees in addition to high densities increase the amount of Douglas-fir beetle-caused tree mortality sustained during an outbreak (Negron et al. 1999).

The montane unit hazard ratings indicate that roughly 26 percent of the area has susceptible Douglas-fir. Moderate and high hazard account for 65 percent of the susceptible area. The proportions equate to about 261,000 acres of moderate and 121,000 of high hazard. These low proportions for high/moderate may indicate a limited potential for a large scale outbreak; however, localized outbreaks are possible especially where other disturbances such as fire or significant western spruce budworm occur, and may impact high value stands such as old growth.

Figure 72 and Figure 73, and Table 43 below display Douglas-fir beetle hazard rating by analysis areas. Moderate and high hazard is roughly the same proportions for all the individual montane units, with slightly more in the Bridgers, Bangtails, and Crazies where cover types with Douglas-fir are more represented. Douglas-fir beetle may capitalize on trees damaged in future wildfires and/or western spruce budworm outbreaks which may increase in extent and severity, allowing populations to build and move into green, healthy forests.

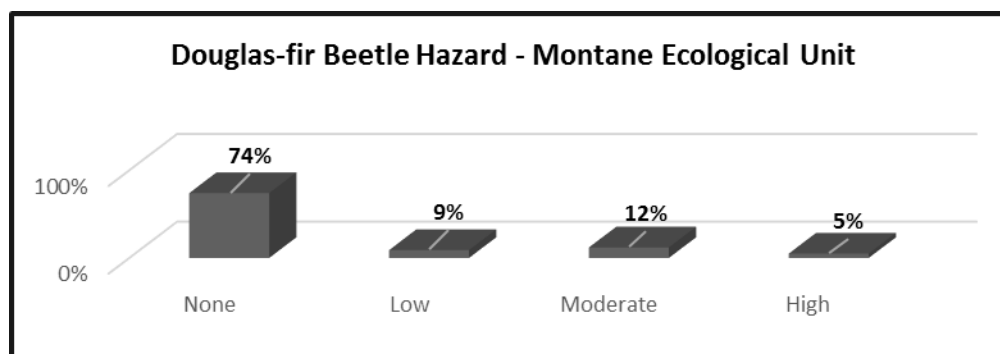


Figure 72. Douglas-fir beetle hazard by proportion of ecological unit, R1 Summary Database, FIA plots

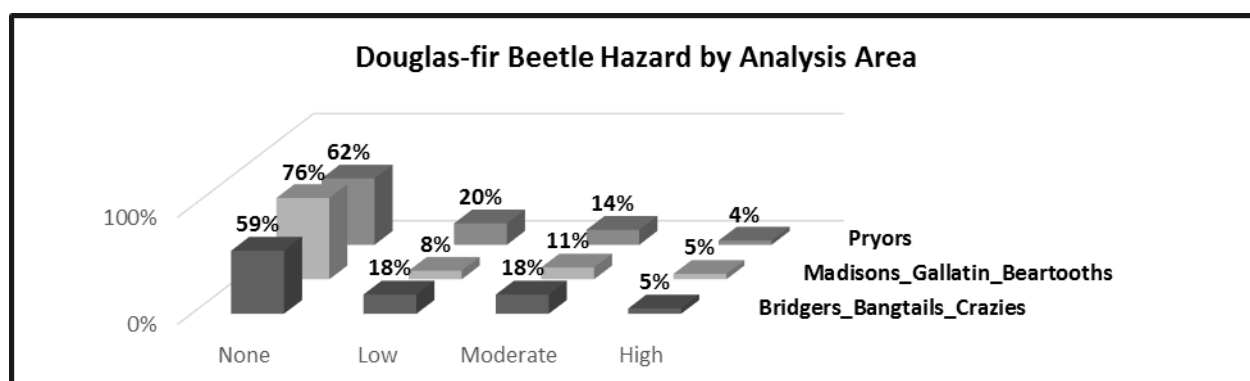


Figure 73. Douglas-fir beetle hazard by proportion of analysis area, R1 Summary Database, FIA plots

Table 43. Acres of Douglas-fir beetle with moderate or high hazard by analysis area, R1 Summary Database, FIA plots

Analysis Area	Acres of Hazard		
	Moderate	High	Total
Bridgers, Bangtails, Crazies	34,688	9,347	44,035
Madison, Henrys Lake, Gallatin, Absaroka and Beartooth Mtns	216,570	109,096	325,666
Pryors	9,681	3,098	12,779
Total	260,939	121,541	382,480

Efforts geared at prevention rather than suppression has the greatest benefits with ongoing or potential beetle infestations (Gibson 2008). Identifying susceptible stands and altering them can help maintain mortality at acceptable levels. Stand manipulation (thinning, regeneration, salvage) that reduce stocking, percent of beetle host, average stand age, or size will produce stand conditions less favorable to Douglas-fir beetles. Removal of larger, older components can greatly reduce future mortality.

### Western spruce budworm

Western spruce budworm outbreak cycles also appear to be increasing in duration because of warm/dry conditions and extent of susceptible host conditions (dense, multi-layered forests of Douglas-fir, subalpine fir and spruce).

Regional forest health protection entomologists and inventory specialists developed a hazard rating system for the western spruce budworm that can be used with inventory data (Randall et al. 2011). The hazard rating uses total basal area of the stand, percent basal area of the host species, and trees per acre. These hazard ratings evaluate the susceptibility of forests by evaluating the quality of the host and quantity of the food source. High hazard is when large amounts of defoliation is expected once an outbreak occurs. Moderate and low hazard stands may experience less defoliation, growth loss, top kill, or mortality. Spruce budworm may not be as active when high hazard stands are intermixed with low hazard stands. Low hazard stands may not have the quality or quantity of host species needed for high defoliator populations. However, they may still cause significant mortality, but overall losses would be less than in high hazard areas that are clustered.

About 1.4 million acres on the montane unit contains susceptible hosts with stand conditions for western spruce budworm defoliation. Of this about 542,000 have been rated a high hazard and 571,000 a moderate hazard. Douglas-fir is widespread across the montane landscape and has dense stand conditions indicative of the defoliator hazard across the individual landscapes. Proportionally the Bridgers, Bangtails, and Crazies have higher amounts susceptible due to more prevalence of cover types that contain host species. Figure 74 and Figure 75, and Table 44 below display western spruce budworm hazards by analysis area.

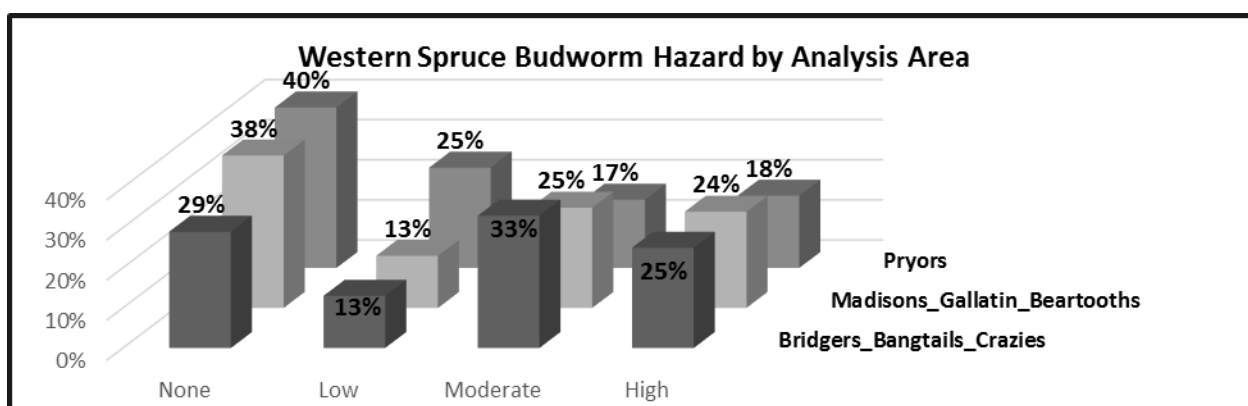


Figure 74. WSBW hazard by proportion of analysis area, R1 Summary Database, FIA plots

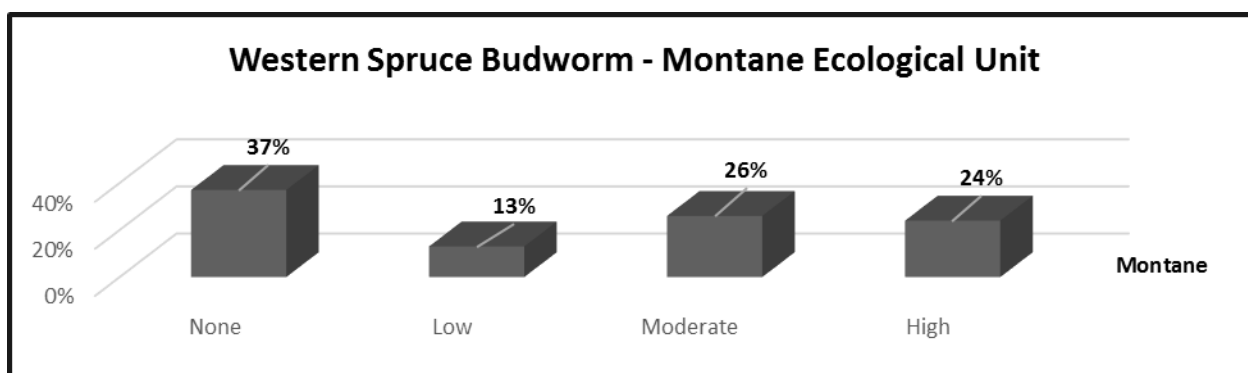


Figure 75. WSBW hazard by proportion of eco, R1 Summary Database, FIA plots

**Table 44. Acres of WSBW with moderate or high hazard by analysis area, R1 Summary Database, FIA plots**

Analysis Area	Acres of Hazard				Grand Total
	Low	Moderate	High	Mod/High Total	
Bridgers, Bangtails, Crazies	25,131	60,961	47,253	108,214	133,345
Madison, Henrys Lake, Gallatin, Absaroka and Beartooth Mtns	225,600	498,039	482,205	980,244	1,205,844
Pryors	17,684	11,618	12,779	24,397	42,081
Total	268,415	570,618	542,237	1,112,885	1,381,270

Maintaining a healthy forest offers the greatest potential for preventing or reducing the severity of western spruce budworm outbreaks (Pederson et al. 2011). Silvicultural options can include both even- and uneven- aged regeneration systems and intermediate treatments. Multi-storied stands of Douglas-fir are most damaged; avoid multi-layered stand conditions where Douglas-fir is in both overstory as well as understory. Intermediate treatments objectives that maintain tree vigor to enhance survival and recovery and selection of phenotypically resistant trees can reduce western spruce budworm effects (ibid). Pesticide treatments offer only temporary protection (2 to 3 years) and should be considered in high recreational sites if visuals is a concern. Desired conditions should accept some defoliation as a normal stand-development process.

### Summary of Expected Future Trend and Ecological Integrity

There is uncertainty in predictions of how climate and other drivers may cause changes in vegetation, thereby influencing feedbacks with insects and disease processes. Interactions between components are complex and change will most certainly occur in these dynamic ecosystems. In some cases changes may be within the natural range of variation and will not negatively impact ecosystem integrity, though they may not be desirable from a social perspective. In other cases the change may render ecosystems less resilient. In areas that experienced previous mountain pine beetle outbreaks, projected forest conditions will resemble pre-mountain pine beetle conditions without management. Temperature increases may predispose forests to stresses through increasingly negative water balances (McKenzie et al. 2007). Trees have natural defense mechanisms to insects and disease, such as using resin to push out invading beetles or re-growing needles after defoliation. Water stress limits the resources available for trees to utilize these survival mechanisms, thereby increasing their likelihood of damage. As host trees respond to climate change, responses will have cascading effects on bark beetle populations. Further investigation, especially in water-limited systems, is needed to increase quantitative understanding of how climate-induced changes in trees will influence bark beetle population success at different scales (Halofsky et al. 2017)

Climate change may affect beetle populations in two ways: directly through insect physiological processes, and indirectly through the effects to host plants and natural enemies (Williams and Liebhold 2002). Climate influences over-winter survival, reproductive rate and success, dispersal ability, and timing of the life cycle of beetles. Expected increases in temperature are likely to affect beetle population growth, but effects may be positive or negative. The response of bark beetle community dynamics to climate change will be ecosystem and species-specific (Bentz et al. 2009, Bentz et al. 2010). All bark beetles are freeze-intolerant, and undergo a cold-hardiness process which serves to lower the temperature at which body tissues freeze; the resulting level of cold tolerance depends on the temperature regime experienced by each individual (ibid). Warmer temperatures, therefore, increase the likelihood of over-wintering beetle survival. As maximum temperatures increase, developmental rates can also increase to a point, and adult emergence and flight may occur earlier, although there is

some risk of disrupting population synchrony and increased mortality in less cold hardy stages (ibid). Given the rapid colonization by mountain pine beetles of former climatically unsuitable areas during the last several decades, continued warming in western North America associated with climate change will allow the beetle to further expand its range northward, eastward, and toward higher elevations (Carroll et al. 2003). Models of potential effect of climate change on mountain pine beetle population dynamics suggest an increase in probability of outbreak potential in higher elevation forests and a decrease in lower elevations for the period 2001 to 2030, compared to 1961 to 1990 (Bentz et al. 2009). Changes in climate may allow bark beetles to move into other ranges of their host species or the ranges of new potential hosts (Williams and Liebhold 2002).

The increased potential for fire extent and severity that may be associated with a warming climate may be exacerbated by increasing insect infestations which create an altered fuel complex; and conversely post-fire conditions will alter future insect activity. In some cases, fire-scorched trees are more susceptible to infestations in the case of Douglas-fir, and may give rise to outbreaks. Conversely, stand-replacing fires may reduce insect activity in lodgepole pine forests.

The diseases on the Custer Gallatin National Forest will continue to be present in the future, and their trend is influenced by many of the same factors discussed for insects. Dwarf mistletoe is common in lodgepole pine and is likely to remain so, although increases in the extent and severity of fires could cause localized reductions in infections.

Root diseases are generally considered permanent fixtures of the site, although it may be more active in areas where species shift toward tolerant species versus those that are dominated by shade intolerant species. The effect of the nonnative white pine blister rust is expected to continue and has no analog in the natural range of variation.

Spatial heterogeneity is important for insect and pathogen regulation; this is largely influenced by feedbacks between wildfire and insect and disease processes. The spatial heterogeneity in stand ages and structures following fire creates complex templates of suitable hosts for bark beetles, while spatial heterogeneity of bark beetle outbreaks creates complex patterns of fuel that influence behavior and severity of future fires (Turner et al. 2012). Spatial variability in post-fire stand density/structure may dampen subsequent bark beetle outbreaks because trees reach susceptible size at different times; intensive forest management with even-aged, even-sized trees may increase vulnerability of forests to certain insects and pathogens (Turner et al. 2012).

## **Vegetation Treatments**

### **Existing Condition**

Forest vegetation on the Custer Gallatin National Forest has been shaped by human intervention. Aboriginal burning likely occurred prior to European settlement. Some records suggest in the pine savanna unit this burning was for getting a fresh crop of grass for grazing their horses and also for easier traveling for the next summer (Gruell 1983). On the montane unit some records indicate purposes included a form of communication and for flushing enemies out (ibid). Early settlement extracted forest products for mining, railroad ties, home building, fence material, and fuel wood. These activities are considered part of the historical condition and are discussed in the heritage section qualitatively. More recent activities in the last 75 years can be addressed quantitatively where data has been recorded in the corporate activity tracking data base (forest activity tracking system). Vegetation treatments discussed in this section are for the period 1940 to 2015. It is realized that this data set is not a

complete record, especially from 1940 to early 1980's when electronic storage was nonexistent and all activities occurring in that period may not have been entered into the electronic data base.

Vegetation management activities have been conducted on the Custer Gallatin National Forest to meet a variety of objectives. It is Forest Service policy (Forest Service Manual 2478.03) to prepare silvicultural prescriptions that detail the methods, techniques, and timing of activities to achieve objectives prior to initiating treatments. This silvicultural practice ensures treatments are suited for the land management objectives for the area, while considering resources, as directed in the forest plans. Vegetation treatments include a variety of treatment types and for this discussion are grouped into three categories: harvest, stand improvement and reforestation, and fuels. These are generally prescribed together on an individual stand to meet management objectives, however in some instances they may be independent. Because of this acres reported in the forest activity tracking system are greater than the foot print of the managed area. This foot print is discussed later in this section.

This section focuses on the impacts of treatments to forest vegetation. Detailed information on timber harvest, wood products, and the suitability of lands for timber harvest are covered in the forest vegetation key benefits to people assessment (Thornburgh 2016).

## Harvest

Timber harvest is defined as the removal of trees for wood fiber use and other multiple-use purposes (Forest Service Manual 1909.12\_zero\_code and 36 Code of Federal Regulations 219.19). Harvest of trees are typically but not always utilized commercially. Harvest activities are utilized to meet multiple resource objectives as allowed for in forest plans which include providing for jobs and wood products to communities; improving forest health, vigor, and productivity; and providing for vegetation diversity. More recently this tool is used to assist in restoration of ecosystem processes, improve resilience, promote certain wildlife habitats, and/or to modify or change fire behavior. Harvest activities can be grouped into three categories:

- **Regeneration Harvest:** Removal of trees intended to assist in the regeneration of a new age class or to make regeneration of a new age class possible. Silvicultural systems used on the Custer Gallatin National Forest include clearcutting, seed tree, and shelterwood. The end result of these systems is the establishment of an early seral component. The age maybe single or two depending on the residual trees remaining after treatment.
- **Uneven-aged Harvest:** Group selection and individual tree selection are both an uneven-aged regeneration method. Both are done with multiple entries that ultimately result in 3 or more age classes. Group selection creates small groups of new age classes while individual tree selection creates a multi-aged structure while providing space for a new age class to develop.
- **Intermediate Harvest:** Intermediate timber harvests are designed to enhance growth, quality, vigor, and composition of the stand prior to final harvest. Treatments include commercial thinning, liberation harvest, sanitation/salvage, and improvement cutting. The end result will alter species composition, density, and structure dependent on objectives.

As indicated earlier harvest activities occurred during and throughout early settlement for extraction of wood products for various needs (mining, railroads, homes, fences, and fuelwood). Often times these early activities were concentrated on the most accessible and productive forested areas. However, in some cases on the pine savanna unit, the majority of land units were cut over. Intensities of these activities varied from taking the largest and best trees (high grading) to removing the majority of the trees in an area depending on what the product was being used for. Evidence of these early activities is

still seen in many areas by decaying stumps. Based on existing vegetation conditions intensely cutover areas regenerated which may have been in part due to cool/moist climate at the time. Genetic diversity may have been reduced during high grading where the best trees were removed and less desirable trees were left to provide seed for regenerating the new forest. While no data is readily available to quantify early harvest activities, they undoubtedly played a role in shaping the existing vegetation conditions.

A suite of resource management laws, such as National Forest Management Act, were enacted in the 1960s and 1970s that regulated vegetation management, and harvest cutting practices in particular, on federally managed lands. Modern harvests are prescribed based on a wide array of objectives coupled with an understanding of site capability, existing and potential vegetation pathways, species ecology, and other resource considerations. For example, even-aged treatments are most often prescribed in lodgepole pine types, which are intended to mimic a stand-replacing disturbance to create a new age class. The array of resource objectives can include, but are not limited to, considerations such as productivity, economic value, habitat, watershed function, forage, biodiversity, insect and disease hazard, and restoration of natural fire regimes.

Harvest activities occurred on about 155,503 acres on the Custer Gallatin National Forest since about 1940 according to forest activity tracking system. This represents about 7 percent of the non-wilderness land base. Of this total harvested acres, 97,329 acres were regeneration, 44,679 acres intermediate, and 13,495 acres uneven-aged. Implementation of regeneration treatments resulted in creating age class diversity. Intermediate harvests altered the structure and composition by generally creating more open, larger diameter stands and usually favoring early seral, shade intolerant species in the mixed conifer stands.

Harvest activities by percent of the non-wilderness land base are about the same for the Madison, Henrys Lake, Gallatin, Absaroka, and Beartooth unit and the Bridgers, Bangtails, and Crazies unit, both around 8 percent. The Madison, Henrys Lake, Gallatin, Absaroka, and Beartooth unit is the largest land base and thus the highest amount of total harvested acres. By contrast, the Pryors land unit is the smallest and only about 1 percent of the land base has had harvest activities. The Sioux District has had the highest amount of its land base with harvest activities (9.5 percent). The Ashland District has had harvest activities occur on about 2 percent of its land base.

**Table 45. Acres of harvest type by analysis area and percent of non-wilderness acreage, FACTS**

Analysis Area	Harvest Type			Total	Non-Wilderness Acres	% Non-Wilderness Area
	Regeneration	Uneven-aged	Intermediate			
Madison, Henrys Lake, Gallatin, Absaroka and Beartooth Mtns	69311	7143	25966.3	102420.3	1292207	7.9%
Bridgers, Bangtails, Crazies	20483	1372	2846	24701	321701	7.7%
Pryors	625		276	901	77944	1.2%
Ashland	1978	2465	6035	10478	501596	2.1%
Sioux	4932	2515	9556	17003	178625	9.5%
Total	97329	13495	44679.3	155503.3	2372073	6.6%

The current Forest Plans include management areas that are tentatively suitable for timber management and management standards pertaining to timber harvest. These plans allow for timber harvest on unsuitable areas to meet resource objectives other than timber production. Since the decision on these

Forest Plans most harvest activities have been done for purposes other than timber harvest. Additional restrictions and guidance for timber harvest activities are included in designated inventoried roadless areas that were designated post forest plan decision. Forest Service policy limits openings in even-aged management to 40 acres, unless specific exceptions apply or the regional forester approves based on an analysis that supports the opening size. See Current Forest Plan directions section above and Key Benefits to People section for additional information on timber harvest and suitability.

## **Stand Improvement and Reforestation**

Reforestation and stand improvement are guided by the same resource management laws and regulations as harvesting. In particular, reforestation is a silvicultural practice critical to the successful management of all forest resources. The laws and regulations allowing timber harvest on National Forest lands include both expressed and implied mandates to reforest.

The National Forest Management Act of 1976, Forest and Rangeland Renewable Resources Planning Act of 1974, Custer and Gallatin Forest Plans, and Forest Service Manual 2479.01 give direction on timeframes and monitoring requirements following management and natural disturbances. The policy of Congress is that all forested lands in the National Forest System be maintained in appropriate forest cover with species of trees, degree of stocking, rate of growth, and conditions of stand designed to secure the maximum benefits of multiple use sustained yield management in accordance with land management plans.

Timber stand improvement refers to intermediate treatments of trees generally not past the sapling stage done to improve the composition, structure, condition, health, and growth of even or uneven-aged stands. Reforestation is the reestablishment of forest cover either naturally (natural seeding) or artificially (by direct seeding or planting). A variety of site preparation activities to prepare the seedbed for natural regeneration or planting has been associated with reforestation on the Custer Gallatin National Forest, including burning, slashing, and hand or machine scarification. While in the past these treatments were primarily tied to harvesting, reforestation, and timber stand improvement activities are increasingly conducted in areas impacted by large wildfires to meet an array of resource objectives. Since the maintenance of adequate stocking in forested areas is required by the National Forest Management Act, post-fire reforestation has been emphasized on the Custer Gallatin National Forest. In addition, reforestation or stand improvement may be desired in areas that are not suitable for timber production because of other resource objectives such as watershed health or wildlife habitat.

- **Stand Improvement:** This treatment category includes pre-commercial thinning, and release and weeding of young stands. These activities alter composition, structure, density, health, and growth of young forested stands to meet various management objectives.
- **Reforestation:** Reforestation includes both artificial (tree planting and direct seeding) and natural regeneration. Reforestation occurs post regeneration harvest treatments and post natural disturbance events (fire, insects). The Custer Gallatin National Forest designs and uses silvicultural harvest treatments that promote natural regeneration. The type of reforestation desired is included in the prescription and the species and densities are based on the management objectives, site conditions, and ecological considerations. In harvest treatment prescriptions there is a determination of which trees are left to provide seed for the new stand. When an adequate seed source is lacking (large natural disturbance events) or there is a desire for species diversity, artificial establishment of seedlings may be prescribed. Local adapted seed sources are used for both seeding and seedlings. Certification of natural and artificial



regeneration occurs when there is adequate tree establishment that meets management objectives.

Since about 1940, the forest activity tracking system indicates roughly 174,855 acres of reforestation and stand improvement activities have occurred on the Custer Gallatin National Forest. About 80 percent of this is reforestation and 20 percent stand improvement activities (Table 46 below). Establishment of a new age class in regeneration treatments and recent and past wildfires has resulted in the reforestation acres. Stand improvement treatments have been largely the result of regeneration and liberation treatments and regeneration in large wildfire areas. The Madison, Henrys Lake, Gallatin, Absaroka, and Beartooth unit has had the largest reforestation and timber stand improvement activities due to the large land base. The Sioux District has the second highest reforestation treatments largely due to the successful artificial and natural regeneration of the 1988 and 2002 wildfires. The Pryor land unit has had the least management acres and wildfire occurrences and therefore the least reforestation and stand improvement acres. There has not been an emphasis to reforest large wildfire areas on the Ashland District until recently; reforestation acres are anticipated to increase in the next several years as this effort is undertaken.

**Table 46. Acres of reforestation and stand improvement treatments by analysis area, FACTS**

<b>Analysis Area</b>	<b>Reforestation</b>	<b>Stand Improvement</b>
Madison, Henrys Lake, Gallatin, Absaroka and Beartooth Mtns	92009	20457.2
Bridgers, Bangtails, Crazies	12506	4074
Pryors	1461	119.3
Ashland	11347.5	5785
Sioux	22381.9	4714.1
Total	139705.4	35149.6
Grand Total	174855	

## Fuels Treatments

In the past (pre 1990) most fuel treatments occurred after harvest to reduce activity fuels and/or prepare the site for reforestation. More recently prescribed fire and fuels treatment activities are implemented with or without harvest to restore ecosystem processes, improve resilience, promote certain wildlife habitats, and/or to modify or change fire behavior. This section covers two general fuel activities and associated acres that have occurred on the Custer Gallatin National Forest. Refer to the Fire/Fuels section on additional information.

- **Prescribed Fire Treatments** – Prescribe fire treatments are planned ignitions. Broadcast burning, underburning, jackpot burning, and burning for site preparation are 3 activities that have been done on the Custer Gallatin National Forest. Most of the stand may experience fire activity or only portions of the stand. Objectives are site specific and defined within the prescription and can include: reduction of natural or activity fuels, reduction of ladder fuels, preparing a seed bed for regeneration, altering species composition, thinning trees, and re-introducing fire as an ecosystem process. All of these activities and objectives may address restoration by creating stand conditions that are more resilient to disturbances.
- **Fuel Treatments** – Fuel reduction treatments are generally done in conjunction with timber harvest, stand improvement, or prescribed fire to alter or reduce activity or natural fuels. They may occur alone where prescribe burning or timber harvest is not feasible or desirable but fuels

reduction is needed. Fuel reduction treatments on the Custer Gallatin National Forest have included: piling, pile burning, chipping or crushing, fuel breaks, slashing, thinning, yarding, pruning, and lopping/scattering. Objectives are similar to those described above and are defined in the site specific prescription.

Approximately 88,990 acres of prescribed fire and 193,770 acres of fuels reduction treatments have been completed on the Custer Gallatin National Forest since about 1940 according to the forest activity tracking system. Many of these activities have occurred on the same treatment units where harvest was conducted. In the 1990 to 1999 decade, prescribed burning peaked on the both the montane unit at about 19,000 acres and on the pine savanna unit around 17,000. The following decade prescribe fire use declined for the Custer Gallatin National Forest by about 13,000 acres. The last five years 2010 to 2015 the prescribe fire use is trending up on the pine savanna unit and down on the montane unit.

**Table 47. Acres of prescribed fire and fuels treatments by analysis area, FACTS**

Analysis Area	Prescribed Fire	Fuels Reduction Treatments
Madison, Henrys Lake, Gallatin, Absaroka and Beartooth Mtns	44938	123238.7
Bridgers, Bangtails, Crazies	4939	17943.4
Pryors	750	1697
Ashland	31961	22170.1
Sioux	6402	28721
Total	88990	193770.2
Grand Total	282760.2	

**Table 48. Acres of prescribed fire by decade by ecological unit, FACTS**

Time Period	Ecological Unit	
	Montane	Pine Savanna
2010-2015	5096	12068
2000-2009	15634	7911
1990-1999	19022	17379
1980-1989	3225	992
1970-1979	4337	13
1960-1969	2850	0
1950-1959	463	
Total	50627	38363
Grand Total	88990	

## Trend

### *Treatment Activity Trends*

Records are not available to quantify historical vegetation records. However, there are historical records that describe early settlement of the Custer Gallatin National Forest and give reference to early use of the timber resource. Indigenous burning likely occurred and is considered part of the natural fire regime. Refer to the heritage assessment for information on historical uses (LaPoint 2016). Some accounts of early use of the resource include:

- Beartooth Face – Timber harvest boomed in 1880s to supply mine timbers, fuelwood for kilns and private use, fencing material, and building lumber (Clark 1982).
- Pryors – Amazing amount of lumbering occurred in the 1890s to 1930s for mine timbers, building lumber. Several sawmills were in operation and in 1910 a tent city was established called “Tie Flats” for the workers cutting railroad ties (Clark 1980).
- Ashland District – In late 1880s, several small sawmills that supplied railroad ties, local needs for post and poles, and building lumber. In 1920s to 1950s major cutting occurred to supply railroad ties (Clark 1980).
- Sioux District – In 1884 a sawmill operated in the West Short Pines until all log-sized trees were cut and then it moved to the East Short Pines and did the same (USDA 1936). Early 1900s several sawmills were located on the district. In 1918 to 1932, a large salvage operation occurred in the 1917 fires (Clark 1980).

Figure 76 shows the trend for the 3 vegetation treatment categories (harvest, fuels - both prescribed fire and fuels reduction, and stand improvement/reforestation) by decade since 1940. Treatment acreage maybe low likely due to incomplete record keeping from 1940 to 1950. The following trends are noted for the last 6 decades:

#### **Montane Ecological Unit**

- Harvest Activities - Peaked in the 1960s around 33,700 acres. For the 1970s and 1980s, harvest varied from 23,000 to 30,000 acres with the highest in the 1980s. The 2000 to 2009 levels dropped significantly to 3,100 acres, with most occurring as intermediate harvest (salvage, commercial thinning). This decline was likely due to litigation, decreased budgets, and less emphasis on the use of timber harvest as a tool for management of the resource. Because of this, forest managers tended to plan smaller harvest acreage and treatment units over the last 15 years. There has been a steady decline in harvest acres since 1980; however, in the last five years, there has been a slight increase over the previous decade.
- Regeneration harvest treatments were dominant through the 1990s; in the last five years, no regeneration harvest occurred. Intermediate treatments became more widely used in the 1980s, and the last five years are 94 percent of the harvest acres. Uneven-aged treatments peaked in the 1970s and have since been used less.
- Fuels and Prescribed Fire Activities - Peaked in the 1990s at about 48,500 acres. Fuels reduction treatments largely follow harvest activities with multiple treatments being done on the same acreage (all included in total). For example, yarding of fuels, piling of the fuels, followed by burning of the pile would result in up to three times the unit acres. Prescribed fire in the 1960s through the 1980s was largely done for site preparation. Beginning in the late 1990s, putting fire on the landscape without harvest or other treatments has been increasing as managers recognize the importance of returning fire as a process to the landscapes. Prescribed burning since the 1950s has been 26 percent of fuels treatment acreage. In the 2000s, it was about 60 percent. Within the last five years, the trend is downward for the use of fire at 32 percent.
- Stand Improvement and Reforestation Activities– Stand improvement activities peaked in the 1980s around 8,400 acres. Tended to follow timber harvest or large fire events. Dropped off in the 1990s as science began emerging about the importance of young moist forests for lynx habitat. The last five years stand improvement has largely been done in the wildland urban interface to alter stand structure to reduce the fuels.

- Reforestation activities peaked in the 1980s around 30,900 acres. These tended to follow timber harvest activities up until the late 1980s and then large fire events. About 30 percent of reforestation activities since about 1940 is planting with minor seeding; the rest is natural regeneration. The last five years reforestation acres is trending up and is expected to increase due to recent large fires and the national and regional priority on reforesting burned-over areas (USDA 2013). National partnerships have assisted in planting efforts over the last decade by assisting in purchase of seedlings and cost of planting.

### **Pine Savanna Ecological Unit**

- Harvest Activities – Peaked in the 1980s at about 7,500 acres. In the early 1990s after the large fires in 1988, managers begin recognizing that without fire and/or management the existing stand structures that had developed over the last 80 years in these dry forest types were not sustainable nor resilient to large disturbance events such as fire. This was particularly evident in the 58,300-acre 1988 Brewer fire on the Sioux Ranger District. Seventy one percent of the forested area experienced an uncharacteristic high mortality stand replacement fire event reducing significant forest cover (Sandbak 2003). Beginning in the early 1990s there was an emphasis to create fuel breaks until further treatments could be planned and implemented. The 1990's harvest acres were largely the result of this effort. In the 2000s an effort begin to treat larger landscapes with an increase in the use of timber harvest to assist in meeting objectives and desired conditions. In 2012, one of these planned efforts that had a sale nearly sold, burned up in the Ash Fire on the Ashland District. Since 1980 there has been a downward trend in harvested acres, with a small increase in the 1990s. In 2010 to 2015 timber as a tool has been emphasized less by forest management with declining budgets and the result has been a large downward trend with only 657 acres harvested between 2010 and 2015.
- Regeneration harvests peaked from 1990 to 2009, with about 2,500 acres in each decade. Intermediate treatments have been the dominated treatment since 1950, occurring on about 57 percent of the total treatment acres. Uneven-aged management, largely individual tree selection harvest, occurred on 18 percent. Ninety nine percent in 2010 to 2015 has been intermediate.
- Fuels and Prescribed Fire Activities – As stated above, forest manager's recognition to alter stand structures in these dry forest types in order to create more resilient conditions, also saw the need to return fire as a process. Integration of fuels reduction treatments and/or prescribed fire with timber harvesting resulted in a peak of about 25,700 acres in the 1990s. Fuels reduction treatments have largely followed timber harvest activities with multiple treatments (that is, yarding, piling, burning piles) being conducted on the same acreage to meet the objectives. Beginning in the 1990s, more fuels thinning, and rearrangement of fuels has been done in preparation of prescribed fire or as stand-alone treatments where prescribed burning cannot be safely done or timber harvests are not feasible or currently planned.
- The Ashland Ranger District has implemented the largest amount of prescribed fire on the Custer Gallatin National Forest and with lower priority for timber harvesting by forest management; fuels managers are tending to have a limited focus to reduce fuels and put fire back on the landscape. In 2010 to 2015 there is an upward trajectory in fuels reduction and prescribed burning acreage, in comparison to the previous decade.
- Stand Improvement and Reforestation Activities – Stand improvement activities peaked in 2000 to 2009. Most Timber stand improvement activities follow timber harvest and this peak mirrors harvest and fuel reduction peaks identified above and displayed in the Figure 76 and Table 49 to Table 55 below. Since about 1940, nineteen percent of the timber stand improvement and

reforestation activities has been timber stand improvement related. Pre 1990, timber stand improvement had a focus in the 1960 fire areas to reduce stocking. Since 2000, an integrated effort for timber stand improvement and fuels reduction has increased on non-harvest acreage. Although there is a high need for timber stand improvement treatments across the landscape; 2010 to 2015 is exhibiting a decreasing trajectory since the peak in the previous decade.

- Reforestation activities peaked in the 1990s at about 16,000 acres. Planting has accounted for about 32 percent of total acres since 1940 and the balance natural regeneration. Planting on the pine savanna unit is prescribed on large wildfire areas that are lacking an adequate seed source to reforest the area naturally. Planting strategies include carefully identifying sites where efforts will be successful; especially while considering drought and potential climate change. Large wild fires in 1988 and 2002, a re-burn of the 1988 fire, resulted in the majority of the 19,500 acres of reforestation activities from 1990 to 2009. Reforesting large wildfires has not been prioritized on the pine savanna unit. Reforesting large fires in 2000 on the Ashland District have only recently been emphasized since the 2012 wild fires. After this fire, an integrated landscape analysis was done that looked at restoration and resiliency treatment opportunities. Lack of forest cover was an issue identified. In order to meet desired conditions in the Forest Plan and maintain forest cover under the National Forest Management Act for a resilient forest, a reforestation strategy was developed (USDA 2014). This effort along with the national and regional reforestation strategy, has assisted in a focus on reforesting these large burned-over areas (USDA 2015).
- A national public interest in reforesting burned areas has resulted in multiple partnerships the last decade that have assisted financially in this effort on the Custer Gallatin National Forest. The last five years (2010 to 2015), there has been an upward trend in reforestation and this trajectory is expected to continue as the forest continues to assess and restore our burned landscapes.

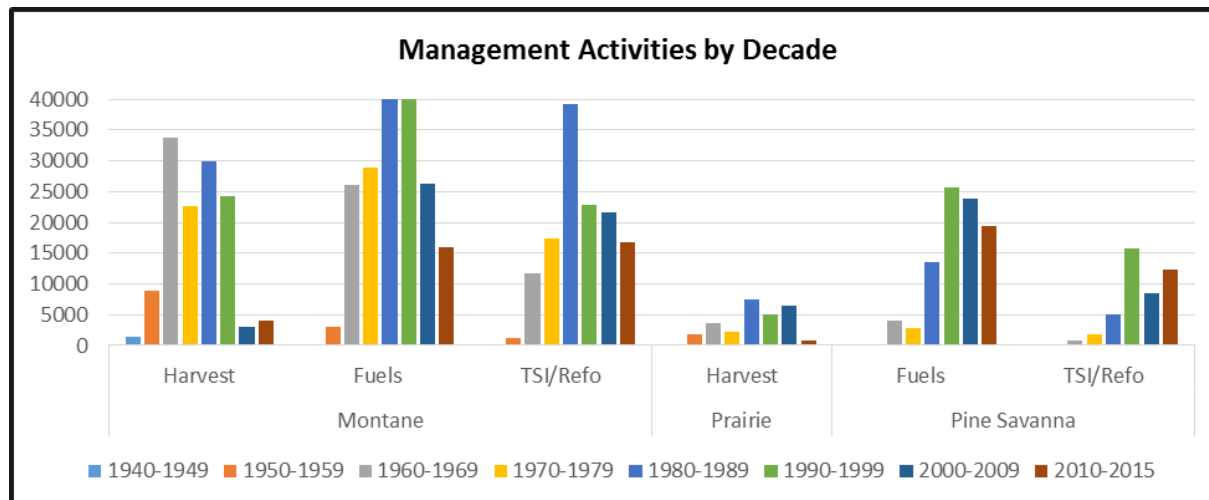


Figure 76. Harvest, fuels, and reforestation treatments by ecological unit by decade, FACTS. See Table 61 for individual acres by analysis area by decade

Table 49. Acres of harvest, fuels and reforestation treatments by ecological unit by decade, FACTS

Year Period	Montane			Pine Savanna		
	Harvest	Fuels	TSI/Refo	Harvest	Fuels	TSI/Refo
1940-1949	1453	142	97	0	0	10
1950-1959	8851	2945	1244	1782	0	17
1960-1969	33756	26019	11784	3563	4080	739

*Custer Gallatin National Forest Assessment – Forested Terrestrial Vegetation*

	<b>Montane</b>			<b>Pine Savanna</b>		
<b>Year Period</b>	<b>Harvest</b>	<b>Fuels</b>	<b>TSI/Refo</b>	<b>Harvest</b>	<b>Fuels</b>	<b>TSI/Refo</b>
1970-1979	22644	28950	17427	2145	2742	1752
1980-1989	29864	44788	39219	7525	13456	5027
1990-1999	24251	48468	22915.3	5133	25705	15780
2000-2009	3112	26255.1	21712	6544	23883	8577
2010-2015	4091.3	15939	16711.7	789	19388.1	12326.5
Total	128022.3	193506.1	131110	27481	89254.1	44228.5
Unit Total	452638.4			160963.6		

**Table 50. Acres of type of harvest by montane ecological unit by decade, FACTS**

<b>Montane</b>	<b>Harvest Type</b>			
<b>Decade</b>	<b>Regeneration</b>	<b>Uneven-aged</b>	<b>Intermediate</b>	<b>Total</b>
2010-2015		231	3860.3	4091.3
2000-2009	1062	99	1951	3112
1990-1999	14104	344	9803	24251
1980-1989	18528	1657	9679	29864
1970-1979	18004	2866	1774	22644
1960-1969	31201	799	1756	33756
1950-1959	7327	1259	265	8851
1940-1949	193	1260		1453
Total	90419	8515	29088.3	128022.3

**Table 51. Acres of type of harvest by pine savanna ecological unit by decade, FACTS**

<b>Pine Savanna</b>	<b>Harvest Type</b>			
<b>Decade</b>	<b>Regeneration</b>	<b>Uneven-aged</b>	<b>Intermediate</b>	<b>Total</b>
2010-2015		3	786	789
2000-2009	2588	113	3843	6544
1990-1999	2450	321	2362	5133
1980-1989	1259	1057	5209	7525
1970-1979	324	530	1291	2145
1960-1969	289	1174	2100	3563
1950-1959		1782		1782
Total	6910	4980	15591	27481

**Table 52. Acres of stand improvement and reforestation by montane ecological unit by decade, FACTS**

<b>Montane</b>	<b>Treatment Type</b>		
<b>Decade</b>	<b>TSI</b>	<b>Reforestation</b>	<b>Total</b>
2010-2015	782.7	15926	16708.7
2000-2009	1639.9	20141	21780.9
1990-1999	6621	16289	22910
1980-1989	8429	30896	39325
1970-1979	6349	11078	17427

*Custer Gallatin National Forest Assessment – Forested Terrestrial Vegetation*

<b>Montane</b>	<b>Treatment Type</b>		
<b>Decade</b>	<b>TSI</b>	<b>Reforestation</b>	<b>Total</b>
1960-1969	1462	10322	11784
1950-1959		1244	1244
1940-1949	17	80	97
Total	25300.6	105976	131276.6

**Table 53. Acres of stand improvement and reforestation by pine savanna ecological unit by decade, FACTS**

<b>Pine Savanna</b>	<b>Treatment Type</b>		
<b>Decade</b>	<b>TSI</b>	<b>Reforestation</b>	<b>Total</b>
2010-2015	1067.1	11259.4	12326.5
2000-2009	2476	6101	8577
1990-1999	2666	13398	16064
1980-1989	3372	1371	4743
1970-1979	872	880	1752
1960-1969	34	705	739
1950-1959	12	5	17
1940-1949		10	10
Total	10499.1	33729.4	44228.5

**Table 54. Acres of fuels treatment by montane ecological unit by decade, FACTS**

<b>Montane</b>	<b>Treatment Type</b>		
<b>Decade</b>	<b>RX Fire</b>	<b>Fuels Reduction</b>	<b>Total</b>
2010-2015	5096	10843	15939
2000-2009	15634	10621.1	26255.1
1990-1999	19022	29446	48468
1980-1989	3274	41514	44788
1970-1979	4288	24662	28950
1960-1969	2850	23169	26019
1950-1959	463	2482	2945
1940-1949		142	142
Total	50627	142879.1	193506.1

**Table 55. Acres of fuels treatment by pine savanna ecological unit by decade, FACTS**

<b>Pine Savanna</b>	<b>Treatment Type</b>		
<b>Decade</b>	<b>RX Fire</b>	<b>Fuels Reduction</b>	<b>Total</b>
2010-2015	12068	7320.1	19388.1
2000-2009	7911	15972	23883
1990-1999	17379	8326	25705
1980-1989	992	12464	13456
1970-1979	13	2729	2742
1960-1969		4080	4080

<b>Pine Savanna</b>	<b>Treatment Type</b>		
<b>Decade</b>	<b>RX Fire</b>	<b>Fuels Reduction</b>	<b>Total</b>
1950-1959			0
1940-1949			0
Total	38363	50891.1	89254.1

## Reforestation Success

Forest regeneration after natural or human disturbance underpins many ecosystem services and may well be a keystone process (Turner et al. 2012). The Forest and Rangeland Renewable Resources Planning Act of 1974 followed by the National Forest Management Act of 1976 states the following:

"It is the policy of the Congress that all forested lands in the National Forest System shall be maintained in appropriate forest cover with species of trees, degree of stocking, rate of growth, and conditions of stand designed to secure the maximum benefits of multiple use sustained yield management in accordance with land management plans".

Reproduction is still important today as we strive to develop resilient forests for our future. If we do not insure the renewal of the forest, the system will begin to function in a manner inconsistent with our goals (USDA, 2015). Forest regeneration may be impaired by both warming climate and increased fire frequency (Turner et. al 2012). Forests today are being impacted by dynamic disturbance events and it will be important to develop a sound reforestation strategy to enable us to sustain resilient forests that can better cope in the face of a changing climate for the next generation. In 2013, the Northern Region developed a reforestation and climate change primer that provides management recommendations on addressing climate change for forest regeneration practices (Scott et al. 2013). In addition the Northern Region has developed a regional reforestation strategy that will assist in development of resilient forests (USDA 2015).

The National Forest Management Act states that reforestation is required within five years after final regeneration harvest. It further indicates that adequate stocking be established after stand-replacing disturbances. Planted and naturally regenerated stands are monitored to ensure sites become restocked. Stands are considered satisfactorily stocked when there is a sufficient quantity of well-established seedlings appropriately distributed as indicted in the silviculture prescriptions. Reforestation success is summarized by reforestation indices reports derived from the forest activity tracking system for the last 10 years in Table 56 below for the congressionally designated Custer National Forest and Gallatin National Forest units below. Both units show a high rate of reforestation success where planting has occurred post-harvest. For planting success in the last 10 years the forest activity tracking system indicates the Custer National Forest at 83 percent and the Gallatin National Forest at 76 percent success rate. Treatment units that are not successful include recent failures due to drought conditions that have not been replanted to date. Natural regeneration post-harvest on the Custer is low at 33 percent success. Four out of six stands were not successful and is due to recent fire activity and delayed monitoring due to access issues across private lands.

**Table 56. Recent reforestation success indicators (last 10 years), FACTS**

<b>Indicator</b>	<b>% of Treatment Units</b>	
	<b>CNF</b>	<b>GNF</b>
Recent Plantation Success following Regeneration Harvest	100%	100%



Indicator	% of Treatment Units	
	CNF	GNF
Recent Plantation Success not related to Regen Harvest	83%	76%
Recent Natural Regeneration Success following Regen Harvest	33%	NA <sup>1</sup>

<sup>1</sup>No stands have been recently harvested prescribed with natural regeneration.

Regeneration timeframe reports from the forest activity tracking system can look at reforestation success by year after regeneration harvest from 1976 to 2012. (Regeneration initiated after 2012 is still in the monitoring phase with less than 5 growing seasons at the writing of this report.). Since 1976, 677 stands have had a regeneration harvest on the Custer National Forest. Of these, 64 percent were satisfactorily stocked within five years and an additional 5 percent were stocked after five years. The Gallatin National Forest had 1,613 stands with regeneration harvest. Of these, 57 percent were satisfactorily stocked within five years and an additional 11 percent were stocked after five years. The reason for the delays likely include failures followed by replanting, delayed germination, or site harshness resulting in slow growth. The remainder 31 percent and 32 percent un-stocked areas may be due to a failure to adequately assess site suitability, reforestation remedies not yet occurring, or in some cases a recent disturbance. It is acknowledged that record keeping in the forest activity tracking system for the Custer Gallatin National Forest has some accuracy issues in the coding of data as it relates to monitoring and regeneration status especially as it relates to recent fire disturbances in the harvest units. As an example, 180 of the 677 stands on the Custer National Forest that were recently harvested had a recent fire event prior to successful regeneration and are now being assessed for reforestation needs. This is a data need and the Custer Gallatin National Forest leadership has recognized this important reforestation task and recently has approved to fill a vacant forest activity tracking system position.

## Managed Area Footprint

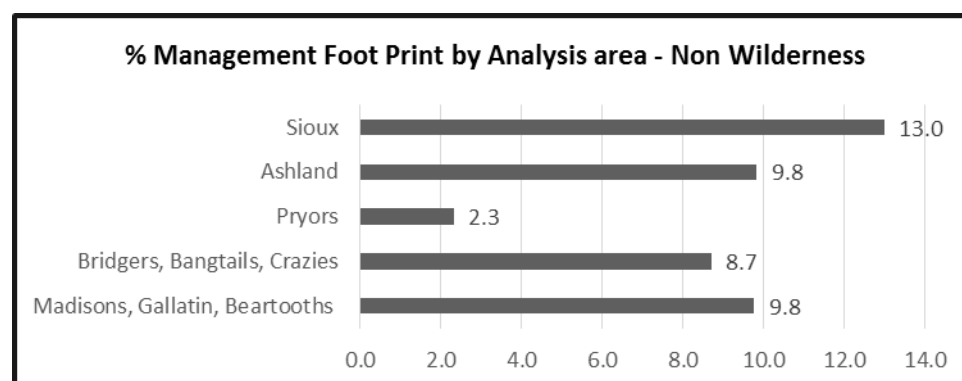
Vegetation management is generally done with multiple types of treatments. For example, a 50-acre forested stand that is harvested, followed by 120 acres of fuels treatments (whole tree yarding, pile, burn piles), 50 acres of planting or natural regeneration, and 50 acres of pre-commercial thinning treatment would have 280 activity acres reported. However, the management foot print is only 50 acres impacted. It is useful to depict the management foot print in order to place treatments in context of landscape patch and pattern.

Completed acres of harvests, fuels (including prescribed fire) and timber stand improvement treatments were queried out of the forest activity tracking system to determine the management footprint. Wildfires and reforestation activities were not included. Reforestation and wildfires (Shea 2016) are discussed separately in other sections. The duplication in treatment activity acres was eliminated by only including the largest and oldest treatment acres per stand in the summary once, although some minor duplication may remain because the forest activity tracking system allows activity areas to overlap. The forest activity tracking system is not a complete historical record of activities. Late 1800s and early to mid-1900s vegetation treatments are not included in this record. Around 1980, the northern region implemented a data base to track accomplishment of vegetation treatments. From this point forward the record is more complete. The management foot print is depicted by percent of analysis area in Table 57 below for 2 periods, 1986 and earlier (pre forest plan) and 1987 to present (post forest plan). The total management foot print is about 228,500 acres or about 10 percent of the non-wilderness acres. Post forest plan the montane unit decreased managed acres by about 16,700 acres while the pine savanna unit increased by about 53,500 acres.

The montane unit has the largest land base and the most acres managed (155,970), the pine savanna unit have had about 72,500 acres managed.

**Table 57. Percent management foot print (harvest, fuels, TSI treatment) pre and post forest plan**

Analysis Area	Analysis Area Acres	Non Wilderness Acres	Foot Print Pre Forest Plan	% Foot Print Pre Forest Plan Non Wilderness	Foot Print Post Forest Plan	% Foot Print Post Forest Plan Non Wilderness	% Total Foot Print
Madison, Henrys Lake, Gallatin, Absaroka and Beartooth Mtns	2343529	1292207	69680	5.4	56504.4	4.4	9.8
Bridgers, Bangtails, Crazies	321701	321701	16004	5.0	11980	3.7	8.7
Pryors	77944	77944	658	0.8	1143.3	1.5	2.3
Ashland	501596	501596	3987	0.8	45310.1	9.0	9.8
Sioux	178625	178625	5491	3.1	17709.6	9.9	13.0
Total	3423395	2372073	95820	4.0	132647.4	5.6	9.6



**Figure 77. Percent management foot print (harvest, fuels, TSI treatment) by analysis area**

The managed footprint for both time periods across the Custer Gallatin National Forest represents about 10 percent of non-wilderness acres. The percentage of each analysis area treated provides a view of how activities have impacted patch and pattern. Even though the Madison, Henrys Lake, Gallatin, Absaroka, and Beartooth Mountains had the most acres treated, it has affected less than 10 percent of the analysis area while the Ashland District, which is smaller, had the same percentage of acres managed. The Sioux analysis area has the highest percentage of its land base managed at about 13 percent. Bridgers, Bangtails, and Crazies have had about 9 percent and the Pryors unit the least at less than 3 percent.

Vegetation treatments result in new age classes and/or manipulations of stand structure and composition. Harvest treatments are generally concentrated within the suitable land base and the current forest plans limit regeneration opening sizes to 40 acres unless specific exceptions apply or a request to exceed was given by the regional forester. In some cases, this may have mimicked natural disturbances, but in many cases the harvest patch size is likely smaller than the natural patterns. On the

west side of the forest, land was acquired that included harvested area and the size of treatment was not restricted to 40 acres or less. In these lands there is a different pattern as a result of larger treatment units.

The distribution and size of harvest patches are likely different than those that would be produced by wildfires. Existing vegetation patterns created by wildfire range from less than one tenth of an acre to tens of thousands of acres on the Custer Gallatin National Forest (also see Fire Section). Maps A1.11 to A1.15 Appendix A depict the harvest and fuel treatment foot print. Harvest activities generally are followed by fuels activities. Maps A1.20 to A1.24 depict the recent wildfire and vegetation treatment pattern foot print (dominance type transitional forest and size class 0 to 4.9 inches). Table 58 and Table 59 below display the number of patches, average size, maximum size, and minimum size by analysis area for the transitional forest and size class 0 to 4.9 inches. See Connectivity section above for additional discussion on these patch sizes

Some fuel treatments have been larger in size and more representative of natural disturbance patterns than harvest. Increasingly, landscape patch and pattern is a consideration for the design of vegetation treatments during the planning stage.

**Table 58. Transitional patch size by analysis area**

<b>Transitional Forest by Landscape Area</b>	<b>Sum Acreage</b>	<b>No. of Patches</b>	<b>Average Size</b>	<b>Maximum Size</b>	<b>Min Size</b>
Ashland	82126	2059	40	6651	<1
Bridgers, Bangtails, Crazies	3506	222	16	611	<1
Madison, Henrys Lake, Gallatin, Absaroka and Beartooth Mtns	180505	2477	73	42551	<1
Pryors	2936	14	210	2685	<1
Sioux	6173	95	65	2554	<1
Grand Total	275246	4867	57	42551	

**Table 59. Seedling and sapling patch size by analysis area**

<b>0-4.9 Tree Size by Landscape Area</b>	<b>Sum Acreage</b>	<b>No. of Patches</b>	<b>Average Size</b>	<b>Maximum Size</b>	<b>Min Size</b>
Ashland	1384	270	5	17	<1
Bridgers, Bangtails, Crazies	7349	638	12	168	<1
Madison, Henrys Lake, Gallatin, Absaroka and Beartooth Mtns	65553	4433	15	2,138	<1
Pryors	2602	162	16	402	<1
Sioux	66	18	4	8	<1
Grand Total	76953	5521	14	2,138	

## Information Needs

Data cleanup in the forest activity tracking system and field assessments are needed to get a better indication of reforestation success in large wildfires areas.

## Restoration and Resiliency

Recently an emphasis by the Forest Service has been placed on enhancing restoration and resiliency of vegetation. These concepts were not included in the Custer and Gallatin Forest Plans; however, they are related to sustainability, which has long been a land management principle. Restoration of forest resiliency in an uncertain future climate will require adaptive management at various spatial and temporal scales.

Ecological restoration has been defined as the practice of reestablishing historical plant and animal communities in a given area and the renewal of ecosystem and cultural functions necessary to maintain these communities now and into the future (USDA 2015b). It is recognized that this ideal may be impossible to manage because: (1) little is known about historic conditions; (2) many key species may already be lost; (3) some efforts may be prohibitively expensive; and most importantly, (4) future climates will create novel ecosystems (ibid). As a result, The Society for Ecological Restoration has opted for a definition that states that ecological restoration is “the process of renewing and maintaining ecosystem health” (ibid).

The Forest Service has defined objectives and a policy (Forest Service Manual 2020) for ecological restoration and include:

- Restore and maintain ecosystems that have been damaged, degraded, or destroyed by reestablishing the composition, structure, pattern, and ecological processes.
- Manage for resilient ecosystems that have a greater capacity to withstand stressors, absorb and recover from disturbances, and reorganize and renew themselves, especially under changing and uncertain environmental conditions.
- Achieve long-term ecological sustainability and provide a broad range of ecosystem services to society.

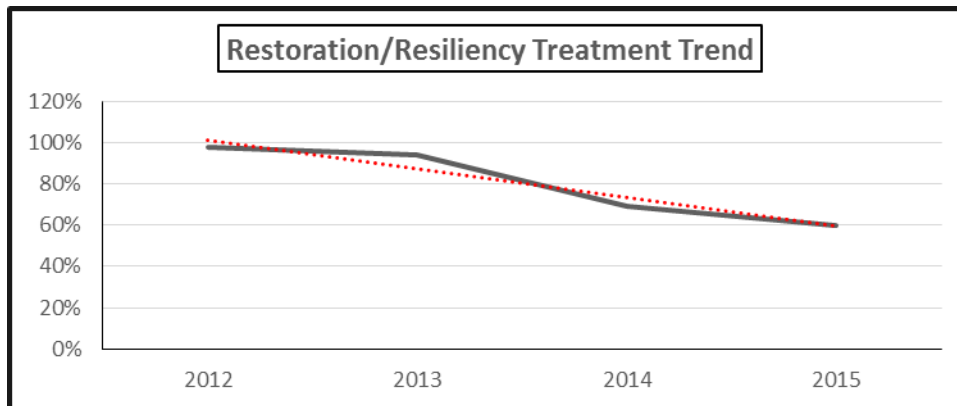
The Northern Regional Office has provided direction for the reporting of these concepts related to management activities; specific restoration goals include (USDA 2013):

- Establish or maintain the proportion of shade-intolerant species. The focus species identified that are present on the Custer Gallatin National Forest include green ash, ponderosa pine, aspen, whitebark pine, spruce/fir lynx winter habitat, and dry Douglas-fir east of the Divide;
- Restore presence or dominance of native grasses and shrubs;
- Restore forest densities and structure to be more resilient to historical and projected disturbance processes in various size classes including wildlife habitats of concern; and
- Promote forest patterns with a range of patch sizes as informed by historical disturbance processes and projected future disturbances and a changing climate.

## Trends and Management Implications

The methods the Northern Region identified that can accomplish these restoration goals can include artificial and natural regeneration, stand improvement, timber harvest, fuel treatments, prescribed burning, and invasive weed treatments. Starting in 2012, about 98 percent of vegetation treatments met the Northern Region’s restoration and resiliency goals (see Figure 78 below). In 2013, there was a slight decline (94 percent) and by 2015 only 60 percent of the vegetation treatments on the Custer Gallatin National Forest met these goals (see Figure 78 below). The species promoted in the plan area have included ponderosa pine, dry Douglas-fir, green ash, whitebark pine, spruce/subalpine fir, and

grass/shrub communities. Restoration and resiliency objectives are expected to be a priority for the planning and implementation of vegetation treatments.



**Figure 78. Percent restoration footprint for the Custer Gallatin National Forest by year**

Reforestation is important because of its influence to future resiliency. Spatial heterogeneity is important to forest regeneration in that the amount and configuration of undisturbed patches and individual legacy trees that survived prior disturbance will be important seed sources (Turner et al. 2012). Through its effects to regeneration, spatial heterogeneity of the landscape therefore impacts primary production, carbon storage, timber production, and wildlife habitat (ibid). Specific reforestation trends will vary by potential vegetation type, and may include changes in the distribution of species due to drought and fire. To retain stand resiliency, managers should maintain as much species diversity as possible and prescriptions should evaluate a range of management options that are reasonable in light of changing site conditions, particularly the assumption of warmer, more arid conditions (Scott et al. 2013). Recommended strategies include, but are not limited to, planting to increase species diversity, favoring early seral species, limiting stand density, maintaining high genetic diversity of seed, following seed transfer guides, using seed from improved seed sources, conserving soil moisture, planting promptly after disturbance, being alert to “savannahfication”, and monitoring (ibid).

One aspect of uncertainty in climate change is that precipitation projections are fairly poor in global climate models (Vose et al. 2016). However, what is consistent is that warming climates are likely to promote drought conditions which can be a severe natural disaster with substantial social and economic consequences (ibid). Increasing droughts can negatively impact forest inventory by increasing mortality and reducing growth; the future extent and severity of drought impacts on western forests raises concern for biodiversity and carbon storage if these trends continue (ibid). Fire occurrence and area burned has been clearly increasing in response to drought (ibid).

Managers can implement structural changes in the forest by vegetation treatments. Thinned stands require less water and may be less vulnerable to water stress and insect outbreaks. Reduced fuel loads in thinned stands can also reduce wildfire risk (ibid). Thinning has long been advocated as a preventative measure to alleviate or reduce the amount of beetle caused tree mortality (Mitchell 1994, Gibson 2004, Fettig et al. 2013). Thinning reduces host availability that supports beetle populations, reduces competition among trees for nutrients, water, and other resources thereby increasing vigor and affects microclimate decreasing the effectiveness of chemical cues used in host finding, selection and colonization and influencing beetle survival. Thinning from below may optimize the effects of

microclimate, inter tree spacing, and tree vigor even if the residual trees are of diameter classes considered more susceptible to attack (Fettig et al. 2013).

Landscapes have tended to become more homogenous as fire is removed because succession will eventually advance all stands to similar communities dominated by shade tolerant species or later successional ages (Keane et al. 2002). Landscape structure (spatial distribution of patches) also changes with fire exclusion as landscapes generally become less fragmented, have lower patch density, and evolve decreased patch diversity, which often results in more contagion, corridors, and large patches (ibid). Altering these homogeneous disturbance susceptible landscapes by changing existing forest structure and composition will increase resiliency (Fettig et al. 2013). Regeneration cutting in small to moderate sized areas will create age and size mosaics within landscapes of homogenous even-aged forests that ultimately reduce impacts by the mountain pine beetle as landscapes will not all be susceptible at the same time (ibid).

Fire resilience and sustainability of dry forest landscapes can be improved by thinning from below and/or applying regeneration harvest systems (Graham et al. 2010). Treatments should emphasize opening up the canopy to relatively wide spacing, reducing canopy layering and removal of the smaller size classes, coupled with prescribed burning and/or mechanical fuel treatment of the natural and activity surface fires. Graham, Harvey, Jain, and Jonalea in 1999 indicated that the best general approach for managing wildfire damage seems to be managing tree density that includes a mix of thinning, surface fuel treatments, and prescribed fire. Other examples have been documented in the literature to support this (Omi et al. 2007, Strom 2005, and Skinner et al. 2004).

Some people believe that silvicultural cuttings are the only feasible method to remove combustible biomass and thereby reducing fire intensities so fire severity will be similar to historical events (Keane et al. 2002). Keane (and others, 2002) also pointed out that others believe that only prescribed fire can only be used to restore landscapes altered by settlement and fire suppression. They also indicated that fire restoration and resiliency treatments cannot be done with just one or two treatment (prescribed burns and/or silvicultural treatments). In fact, some field and simulation studies have shown that it may take as many as 50 to 75 years or at least two and as many as seven fire treatment or rotations to restore native fire regimes to stands and landscapes where fire has been excluded (Baker 1993, 1994; Keane et al. 2002). Because it may take more than one treatment to accomplish the objectives, monitoring will be essential to determine if treatments have obtained goals for restoration and resiliency treatments.

## Information Needs

Vegetation and timber output modeling that includes disturbance processes such as fire, insects, and climate is needed to better understand how existing and forest management and treatments have and may continue to influence ecosystem resilience.

## Key Findings

This assessment reveals that an enhanced consideration of the influence of natural disturbance processes and future climates on the sustainability and resiliency of forested vegetation is warranted in the revised forest plan. The combined effects of numerous interacting factors including fire exclusion, past management activities, climate change, recent large wildfires, and invasive species have compromised the ecological integrity and resiliency of the Custer Gallatin National Forest forested landscapes. However, the specific ecological effects and management implications of these stressors varies substantially by landscape and potential vegetation type. For example:

- Forests in the warm dry potential vegetation type are significantly departed from historical conditions in terms of their current structure, composition, and function, leading to low ecological integrity and high risk of loss. Primarily due to fire exclusion, these historically frequent-fire forests of the Custer Gallatin National Forest have higher densities of trees, increased fuel loadings, and altered species composition. This stress makes these systems more susceptible to insect and disease outbreaks and uncharacteristic proportions of high-severity, stand replacing fire, as demonstrated by recent fire activity in the pine savanna unit. For fire-adapted vegetation types, there is a need to recognize the natural role of fire in the landscape and restore forest structure, composition and spatial patterns that are resilient to future fires, beetle outbreaks and drought.
- In the cool moist potential vegetation type, management activities and fire regime changes have shifted successional pathways from dynamic fine scale mosaics driven by mixed-severity fire to coarser grained, more homogenous patch types driven by high-severity fire. Fire suppression (particularly of small fires) has had the effect of decreasing acreage burned in normal fire seasons and reducing the natural variability in landscape patterns. These vegetation changes and management activities have shifted fire regimes toward less frequent, but larger and more severe fires, which tend to simplify the landscape into fewer, larger, and less diverse patches resulting in more homogenous conditions. In general, these forests are denser and more uniform in structure than they were historically. As a result, the larger, contiguous blocks of uniform stands are subject to large beetle outbreaks and uncharacteristic fires when fire weather is extreme. There is a need to recognize the effect that historic disturbance regimes had in creating mosaics of patch types and restore successional diversity landscapes that are resistant and resilient to current and future stressors.
- In the cold forest potential vegetation type, whitebark pine has been declining rapidly from the combined effects of native mountain pine beetle outbreaks, fire exclusion, and the spread of the exotic white-pine blister rust. This is of major concern because whitebark pine is both a keystone species, because it supports unique community diversity, and a foundation species because of its roles in promoting community development and stability. Within the last decade, major outbreaks of pine beetle and increasing damage and mortality from blister rust have resulted in cumulative whitebark pine losses that have altered high-elevation community composition and ecosystem processes. Due to its critical ecological role and high risk of loss, there is a need to develop forest plan guidance that will help increase resistance and resilience of whitebark pine ecosystems.

Following are findings of the existing forested vegetation characteristics of ecosystems on the Custer Gallatin National Forest:

## **Composition**

- Montane Ecological Unit - A diversity of forested habitat type groups occur ranging from hot dry low elevation sites to cold high elevation sites. A variety of forested cover types occur dependent on growing requirements. From low elevation, dry sites to mid elevation, moist sites to high elevation/cold sites these generally include: limber pine, ponderosa pine, Douglas fir, lodgepole pine, Engelmann spruce, subalpine fir and whitebark pine. Juniper is most common in the lower, dryer forest types and aspen is the most common deciduous tree in the low to mid elevation sites.

- Pine Savanna Ecological Unit – Two habitat type groups - warm dry and moderately warm dry occur on the pine savanna unit. Ponderosa pine is the only needled conifer present. Juniper is present while aspen and green ash are common in the moist areas.
- Large fire disturbances from 2000 to 2012 have resulted in non-stocked potential forested sites on both the montane and the pine savanna units due to recent fire disturbances (2000 to 2012). Cool, moist, and cold types currently have the least amount of non-forested conditions; dry forest types the largest amount. The pine savanna unit contains the largest amount of area currently non-forested (36 percent).
- Whitebark pine is present on approximately 420,000 acres on the montane unit and is currently at risk from climate change, white pine blister rust, and mountain pine beetle. Fire suppression is promoting conversions of WBP sites to shade intolerant species.
- Limber pine is present on approximately 155,800 acres on the montane unit and is subject to the same risks as whitebark pine.
- Species present on the montane unit include: common species are subalpine fir (61 percent), spruce (42 percent), lodgepole pine (37.8 percent), Douglas-fir (31.8 percent), and whitebark pine (24.9 percent); while limber pine (8 percent) and juniper (3.2 percent) are less common; and aspen, ponderosa pine, cottonwood, and paper birch are uncommon to rare presence.
- The pine savanna unit is currently dominated by a non-forested cover type (70 percent). Presence of ponderosa pine is 43.5 percent, juniper is 11.3 percent, green ash is 3.2 percent, and aspen is 0.3 percent of the area.

## **Structure:**

- Size Class - Live small (5 to 9.9 inches in diameter at breast height) and medium (10 to 14.9 inches in diameter at breast height) tree classes tend to be the most dominant size classes. Large (15 to 19.9 inches in diameter at breast height) tree class typically has a higher presence in moist and cooler forest types. Very large (more than 20 inches in diameter at breast height) tree class is rare or non-existent across all forest types.
- Large Live Trees - Presence of individual trees 15 inches and larger are more common in the montane unit and less common in the pine savanna unit.
- Canopy Density Class - Moderate (26 to 40 percent canopy cover) to moderate/high density (40 to 59 percent canopy cover) classes tend to be more common on the dry forest types and moderate/high to high (60 percent plus canopy cover) tend to be more common on the moist to cold forest types. Cool and dry to moist forest types contain the highest proportions of high canopy densities. Cool moderately dry to moist forest types is most common on the montane unit and has the highest amount of area in density class greater than or equal to 40 percent.
- Vertical Structure - Single and/or two story structure tends to be more common across the landscapes with a higher proportion of 3 or more canopy structures in moist and cold forest types.
- Dead Trees, Snags - Snags tend to be less per acre on the dryer forest types and more per acre on the cooler and wetter forest types. Medium sized snags (10 to 14.9 inches in diameter at breast height) are most prevalent on both the montane and pine savanna units. Large snags (15 to 19.9 inches in diameter at breast height) less common and very large snags (20 inches in diameter at breast height or more) are rare.



- Large Woody Debris - Tonnage of large downed woody debris (greater than or equal to 3 inches in diameter) tends to be lower on dry forest types than on cooler moist types. Pine savanna unit is estimated at 1.6 tons per acre and the montane unit at 8.1 tons per acre.
- Old Growth - The montane unit has a higher proportion of old growth (20.1 percent) than the pine savanna unit (2.8 percent). Spruce fir, lodgepole pine, and whitebark pine cover types have the highest amount of old growth.
- Age Class - All habitat type groups except the warm dry type have a 55 to 70 percent of the area in age class of 20 to 100 years. The warm dry type has 34 percent. Cold and timberline types both have 5 percent of the area in a 200 year plus class. Hot dry, cool moist, and cool wet types have no 200 year plus class.

## **Function**

- Pine Beetles – Moderate/high hazard to mountain pine beetle and pine engraver beetle occurs on 33 percent of both the hot dry and warm dry forest types where ponderosa pine and/or limber pine are dominant. Moderate/high hazard occurs on 29 to 56 percent on the cool moist, cool wet, cool moderately dry to moist, cold, and timberline types where lodgepole pine cover type and whitebark pine cover type are common or dominant. The cool to moderately dry to moist forest types have the second highest moderate/high hazard at 47 percent where lodgepole pine cover type is dominant. The highest amount of moderate/high hazard occur in the cold type (56 percent). The timberline type has 44 percent in the moderate/high hazard. These two types have the largest amount of whitebark pine.
- Douglas-fir Beetle - Moderate to high hazard to Douglas-fir beetle is highest on the on the hot dry, moderately warm dry, cool moist and cool moderately dry to moist forest types (23 to 36 percent).
- Western Spruce Budworm - Moderate to high hazard to the western spruce budworm occurs on 33 to 38 percent of the hot dry and moderate warm dry forest types where Douglas-fir is common with multiple canopy layers occur. The highest amount of area (46 to 63 percent) in a moderate/high hazard occurs in the cool to cold forest types that contain multiple hosts and where host species are more common and multi canopy layers occur (Douglas-fir, subalpine fir, and Engelmann spruce).

## **Vegetation Drivers and Trends**

- Climate - Considerable natural variation in climate occurred historically and will continue. Different climate models project differing rates of change in temperature and precipitation because they operate at different scales, have different climate sensitivities, and incorporate feedbacks differently. However, climate models are unanimous in projecting increasing average annual temperatures over the coming decades. Continued and/or increasing drought will likely further limit the carrying capacity of sites, resulting in altered composition, structure, or even lifeform (grass/shrub versus forest vegetation) especially on low elevation sites.
  - ♦ Historically, the climate of the Northern Region has fluctuated between cool and warm periods. Climate has been the major driver of large fire years throughout the last 140-year period in the Northern Region. Drought is a common disturbance force that drives many ecosystem processes during warm periods. It is clear that drought and associated temperature changes can significantly influence outbreaks of forest insects.

- **Vegetative Succession** - Succession is the progression of change in composition, structure, and processes of a plant community through time. Commonly described by the following pathway: seral or successional stage followed by a series of intermediate successional stages (referred to as mid and late successional stages), and culminated by a climax community. In disturbance-prone ecosystems, the climax state may rarely if ever be achieved because succession is commonly interrupted by drivers such as wildfire. As seen in recent large stand replacement uncharacteristic fires on both the pine savanna and montane units which have reset the successional stage.
- **Insects and Diseases** - Insects and diseases are important ecosystem drivers as they can influence vegetation on a local and landscape level. Overtime these agents can change forest compositions and structure.
  - ♦ **Pine Bark Beetles** – The montane unit have had about 1.1 million acres detected with mountain pine beetle between 2000 and 2015. Highest levels were detected between 2007 and 2011. Levels in lodgepole pine peaked in 2009 with a downward trend since. In whitebark pine and limber pine, levels peaked in 2009 as well, but there were elevated levels in 2004 and 2011. From 1971 to 1998, mountain pine beetle was detected in all but 5 years. A mountain pine beetle outbreak occurred in 1975 to 1984 on about 3,522,670 acres; all other years, mountain pine beetle detection was less than 3,000 acres per year. Forty percent of the forested montane landscape is currently at a moderate/high hazard to pine bark beetles.
  - ♦ On the pine savanna unit, three moderately small peaks of infestations occurred in 2003, 2004, and 2005. All other surveyed years that had detected bark beetle infestations were at levels less than 1000 acres. Peaks are generally correlated to severe drought conditions or post wildfire. The largest detections of mountain pine beetle occurred in 1981 (approximately 8,400 acres) and in 1985 (approximately 60,400). All other survey years, mountain pine beetle was detected at low levels. Discounting 1985 (the highest outbreak year), there is a small increasing trend of average acres per year of bark beetle (mountain pine beetle and pine engraver beetle) detection from 2000 to 2015 as compared to 1971 to 1999 surveyed years. Thirty seven percent of the forested montane unit is currently at a moderate/high hazard to pine bark beetles.
  - ♦ **Douglas-fir Beetle** – Douglas-fir beetle is the most destructive bark beetle of Douglas-fir in the northern Rocky Mountains. Douglas-fir only occurs on the montane unit. From 2000 to 2015 there has been about 39,000 acres detected with Douglas-fir beetle. Highest peak levels were detected in 2003, 2005, 2007, 2010, and 2013 with an overall downward trend. Douglas-fir beetle has been at endemic levels across the montane unit on the Custer Gallatin National Forest. Spikes in infestation levels can be attributed to fire events and/or drought weakened trees. Infestation on large diameter trees can be associated with stands that have high defoliation levels from the western spruce budworm. Douglas-fir beetle had an outbreak on about 21,000 acres in 1964. Three other smaller outbreaks between 2,700 and 3,900 acres per year occurred in 1992, 1994, and 1988. All other years, Douglas-fir beetle has been at low levels. Seventeen percent of the forested montane unit is currently at a moderate/high hazard to Douglas-fir beetles.
  - ♦ **Western Spruce Budworm** - Western spruce budworm is the most widely distributed and destructive defoliator in the western United States. From 2000 to 2015, the montane landscapes have experienced western spruce budworm outbreaks in all but the first 2 years. Three peaks have occurred in 2006, 2009, and 2012, all over 100,000 acres. The highest

infested acreage occurred in 2009 at about 200,000 acres with the total infestation acres at about 1 million acres. Western spruce budworm has been present with regular outbreak cycles from 1962 to 1999. There has been 4 peak levels: 1964 (approximately 304,000 acres), 1977 (approximately 203,000 acres), 1980 (approximately 240,500 acres), and 1984 (approximately 957,700 acres). From 1995 to 1999 no detections were documented. Fifty percent of the forested montane unit is currently at a moderate/high hazard to western spruce budworm.

- ♦ **White Pine Blister Rust** - Blister rust is wide-spread and continuing to increase in incidence and severity. Infection rates in monitored Greater Yellowstone Area plots average 20% and range from 0 percent to 84 percent. Whitebark pine is highly vulnerable to infection by blister rust, however approximately 26 percent of the Greater Yellowstone Area population showing genetic resistance to the rust. Mountain pine beetle may be killing trees with natural blister rust resistance creating a need for restoration activities to save some of the trees to beetle attack. Warmer moister climates may favor mountain pine beetle and create wave years for white pine blister rust infections further impacting whitebark pine.
- ♦ **Vegetative Treatments** - Forest vegetation on the Custer Gallatin National Forest has been shaped by human intervention. Early settlement extracted forest products for mining, railroad ties, home building, fence material, and fuel wood. More recent activity acreage (those recorded in the forest activity tracking system) of harvest, reforestation/timber stand improvement from 1940 to 2015 include:

**Harvest** - Harvest activities have occurred on about 155,503 acres. This represents about 7% of the non-wilderness land base. Of this total harvested acres, 97,329 acres were regeneration, 44,679 acres intermediate, and 13,495 acres uneven-aged.

- On the montane unit, harvest peaked in the 1960s around 33,700 acres. For the 1970s and 1980s, harvest varied from 23,000 to 30,000 acres with the highest in the 1980s. The 2000 to 2009 levels dropped significantly to 3,100 acres. There has been a steady decline in harvest acres since 1980; however, in the last five years there has been a slight increase over the previous decade
- On the pine savanna unit, harvest peaked in the 1980s at about 7,500 acres. Since 1980, there has been a downward trend in harvested acres, with a small increase in the 1990s followed by a large downward trend with between 2010 and 2015.

**Reforestation/Timber Stand Improvement** - Roughly 174,855 acres of reforestation and stand improvement activities have occurred. About 80 percent of this is reforestation and 20 percent stand improvement activities. Establishment of a new age class in regeneration treatments and recent and past wildfires has resulted in the reforestation acres. Stand improvement treatments have been largely the result of regeneration and liberation treatments and regeneration in large wildfire areas. Reforestation acres are anticipated to increase in the next several years as an effort is undertaken to reforest large wildfire areas.

- On the montane unit, stand improvement activities peaked in the 1980s around 8,400 acres then dropped off in the 1990s. Reforestation activities peaked in the 1980's around 30,900 acres. The last five years reforestation acres is trending up and is expected to increase due to recent large fires and the national and regional priority on reforesting burned over areas.
- On the pine savanna unit, stand improvement activities peaked in 2000 to 2009, with 2010 to 2015 exhibiting a decreasing trajectory.

- Reforestation activities peaked in the 1990s at about 16,000 acres.
  - The last five years (2010 to 2015), there has been an upward trend in reforestation and this trajectory is expected to continue as the forest continues to assess and restore our burned landscapes.
- ♦ Fuels Treatments - Approximately 88,990 acres of prescribed fire and 193,770 acres of fuels reduction treatments have been completed. Many of these activities have occurred on the same treatment units where harvest was conducted. In the 1990 to 1999 decade, prescribed burning peaked on the both the montane unit at about 19,000 acres and on the pine savanna unit around 17,000. The following decade, prescribe fire use declined by about 13,000 acres. The last five years, 2010 to 2015, the prescribe fire use is trending up on the pine savanna unit and down on the montane unit.

**Management Foot Print** - The total management foot print for the Custer Gallatin National Forest is about 228,500 acres or about 10 percent of the non-wilderness acres. Post forest plan, the montane unit decreased managed acres by about 16,700 acres while the pine savanna unit increased by about 53,500 acres. The montane unit has had the largest land base and the most acres managed (155,970), the pine savanna unit has had about 72,500 acres managed.

**Restoration and Resiliency** - Recently an emphasis by the Forest Service has been placed on enhancing restoration and resiliency of vegetation. The Forest Service has defined objectives and a policy for ecological restoration and the Northern Region has provided direction for the reporting of these concepts related to management activities.

- Reforestation is important because of its influence to future resiliency. Through its effects to regeneration, spatial heterogeneity of the landscape therefore impacts primary production, carbon storage, timber production, and wildlife habitat. Warming climates are likely to promote drought conditions with fire occurrence and area burned increasing. Managers can implement structural changes in the forest by vegetation treatments. Thinned stands require less water and may be less vulnerable to water stress and insect outbreaks. Reduced fuel loads in thinned stands can also reduce wildfire risk. Landscapes have tended to become more homogenous when fire is removed because succession eventually advances stands to similar communities dominated by shade tolerant species or later successional ages. Landscape structure (spatial distribution of patches) also changes with fire exclusion as landscapes generally become less fragmented, have lower patch density, and evolve decreased patch diversity, which often results in more contagion, corridors, and large patches. Altering these homogeneous disturbance susceptible landscapes by changing existing forest structure and composition will increase resiliency. Regeneration cutting in small to moderate sized areas will create age and size mosaics within landscapes of homogenous even-aged forests that ultimately reduce impacts by the mountain pine beetle as landscapes will not all be susceptible at the same time.
- Starting in 2012, about 98 percent of vegetation treatments on the Custer Gallatin National Forest met the Northern Region's restoration/resiliency goals. In 2013, there was a slight decline (94 percent) and by 2015 only 60 percent of the vegetation treatments on the Custer Gallatin National Forest met these goals. The species promoted in the plan area have included ponderosa pine, dry Douglas-fir, green ash, whitebark pine, spruce/subalpine fir, and grass/shrub communities.

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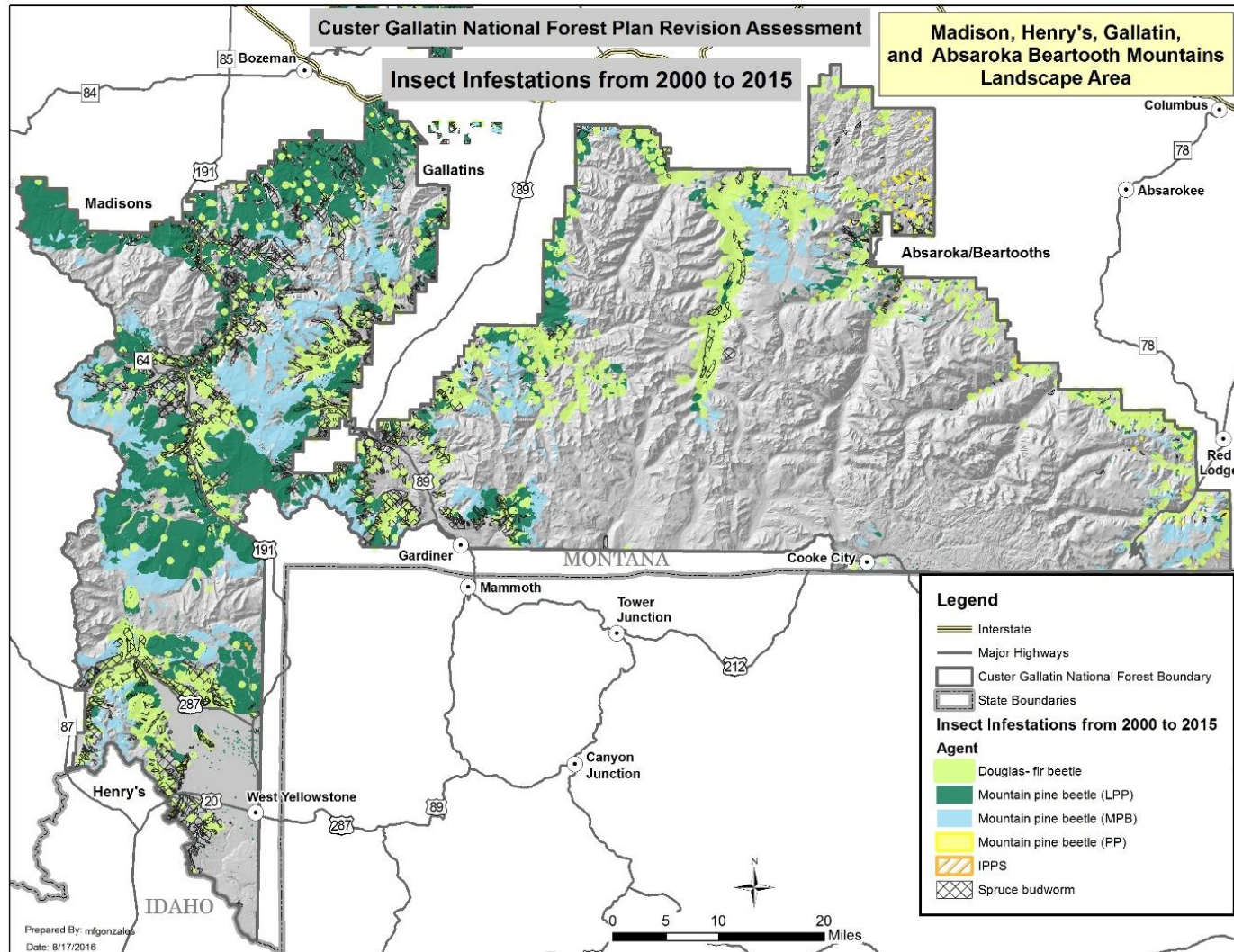
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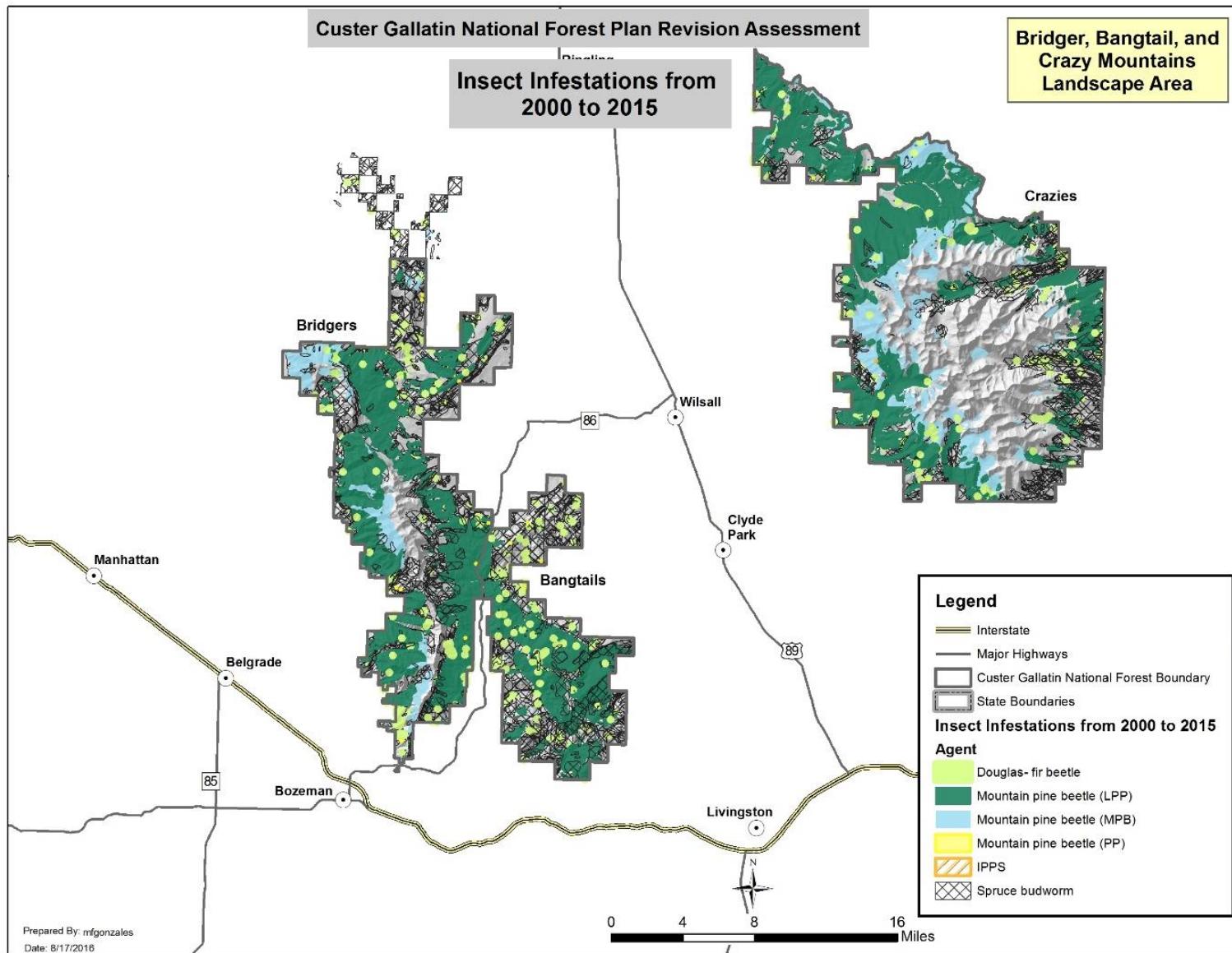
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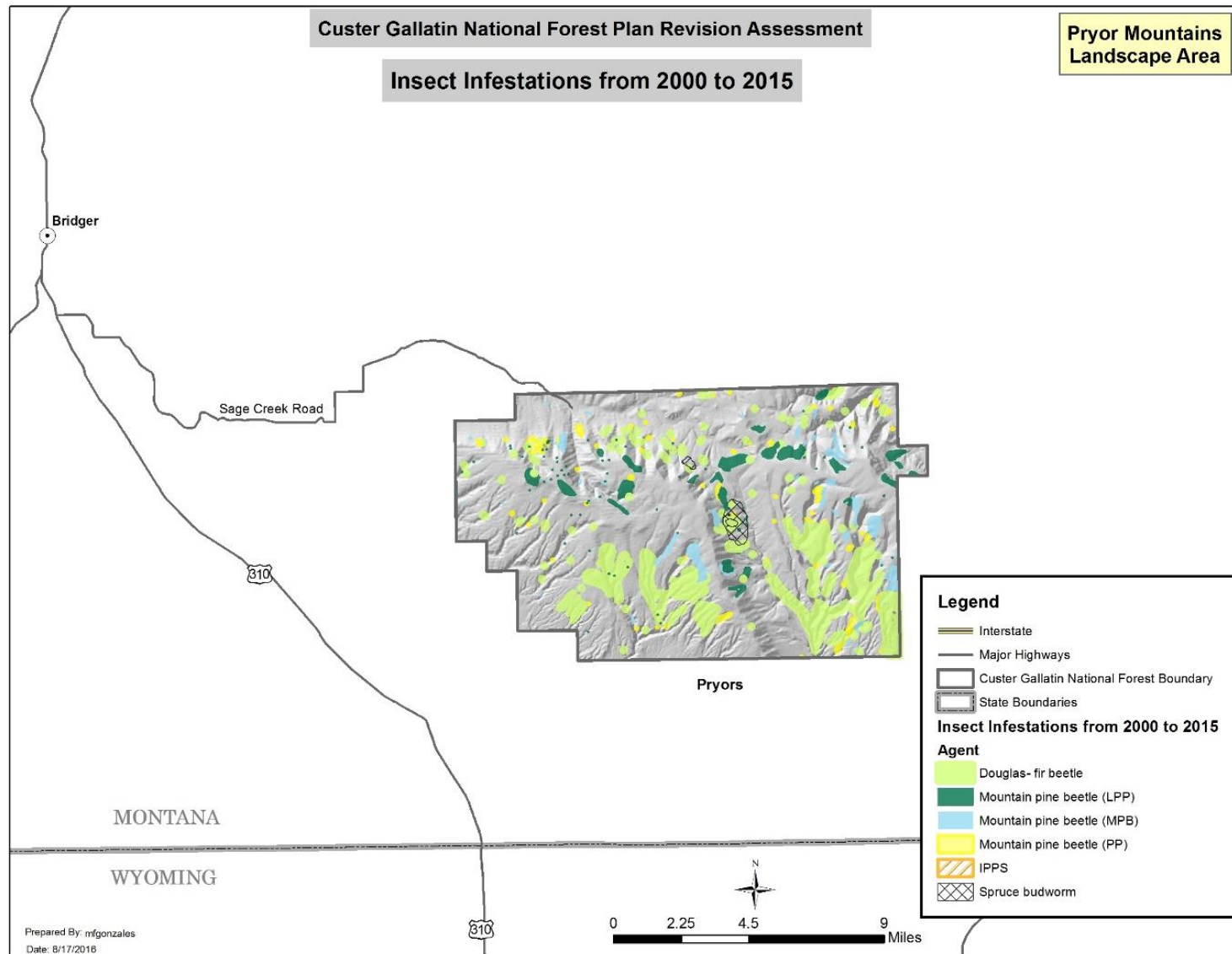
## Appendix A



**Figure 79. Cumulative mountain pine beetle caused mortality from 2000 to 2015 on the Madison, Henrys Lake, Gallatin, Absaroka and Beartooth Mtns analysis area, R1 USDA R1-FHP Aerial Detection Surveys**

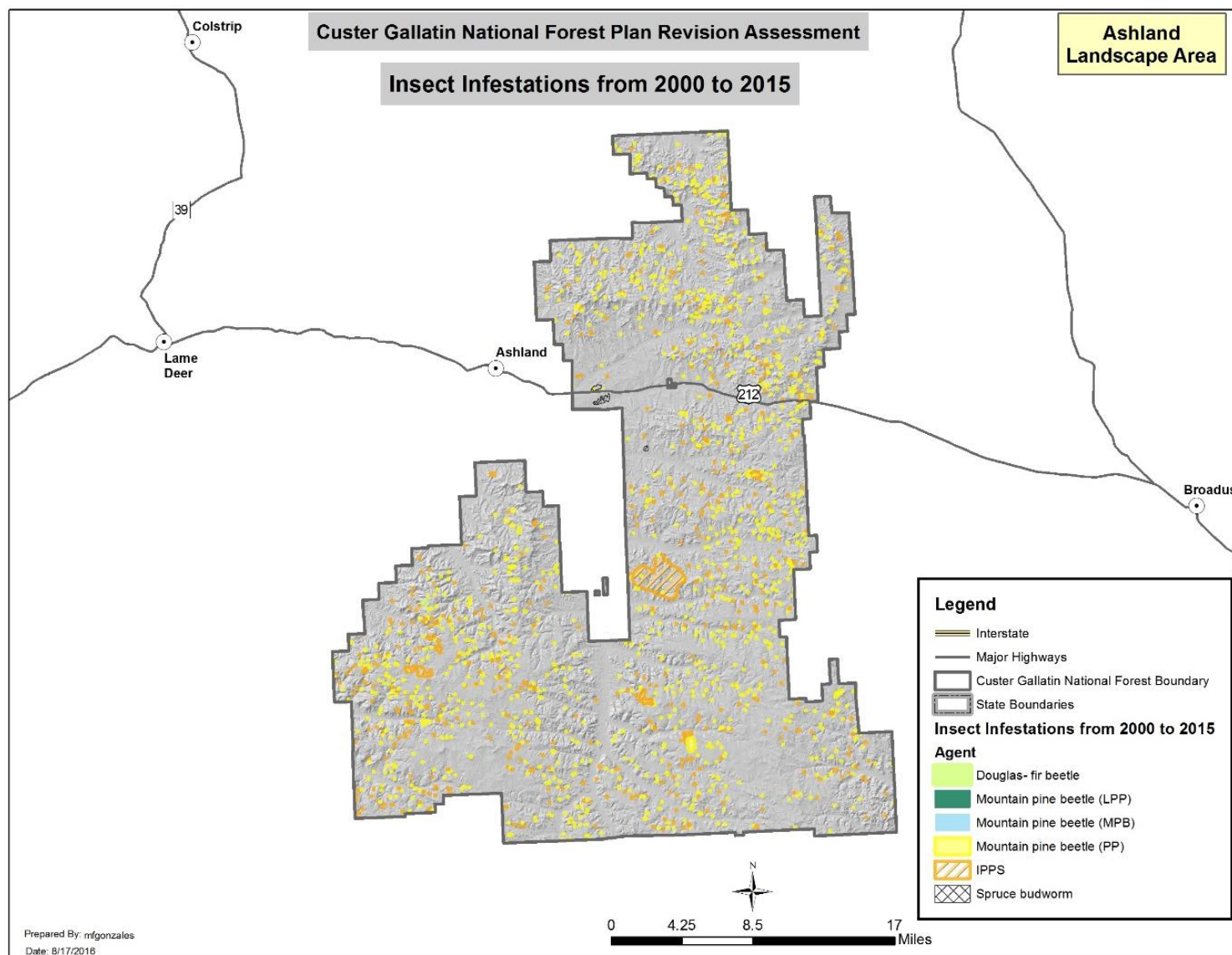


**Figure 80. Cumulative mountain pine beetle caused mortality from 2000 to 2015 on the Bridgers, Bangtails, and Crazies analysis area, R1 USDA R1-FHP Aerial Detection Surveys**

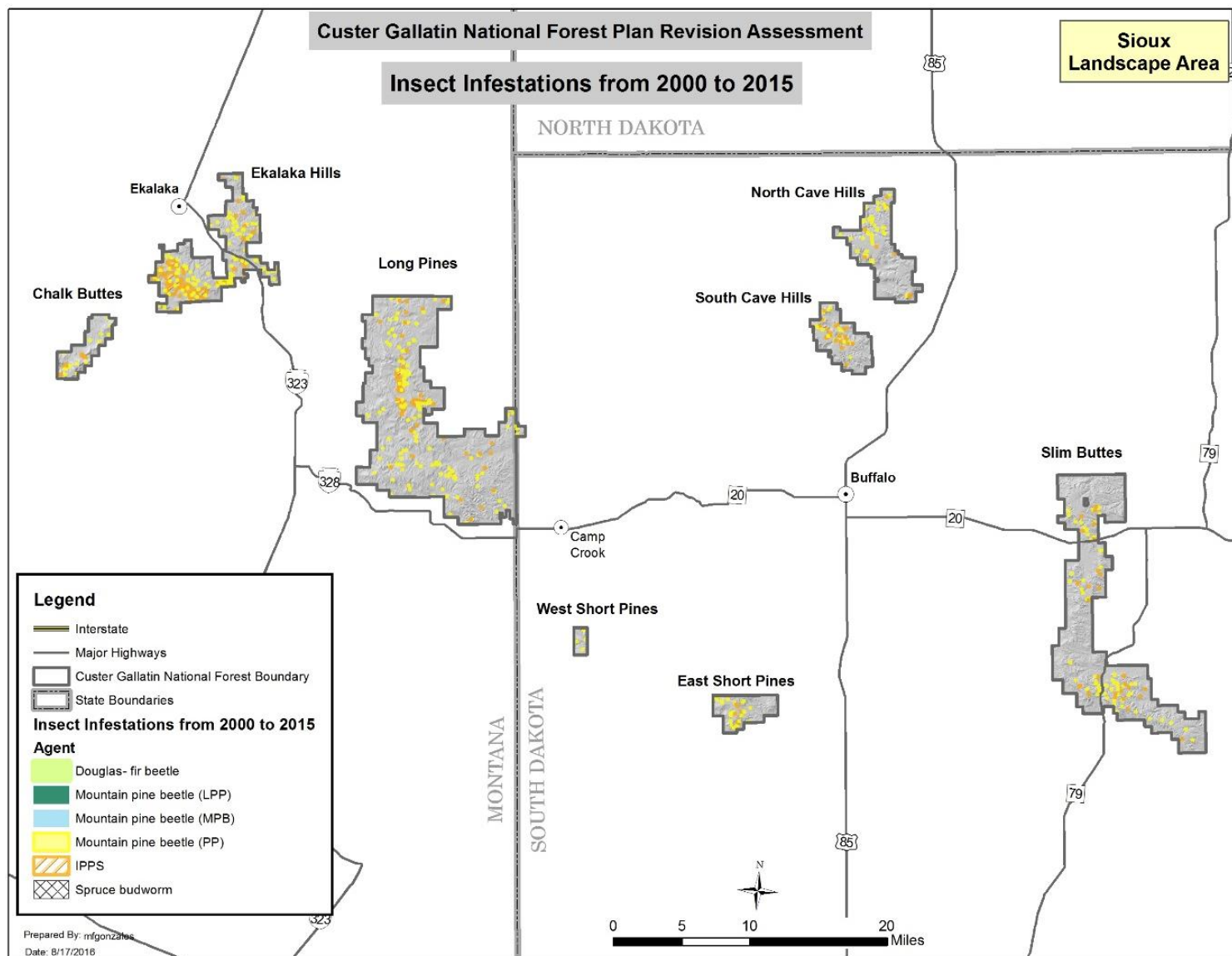


**Figure 81. Cumulative mountain pine beetle caused mortality from 2000 to 2015 on the Pryor analysis area, R1 USDA R1-FHP Aerial Detection Surveys**

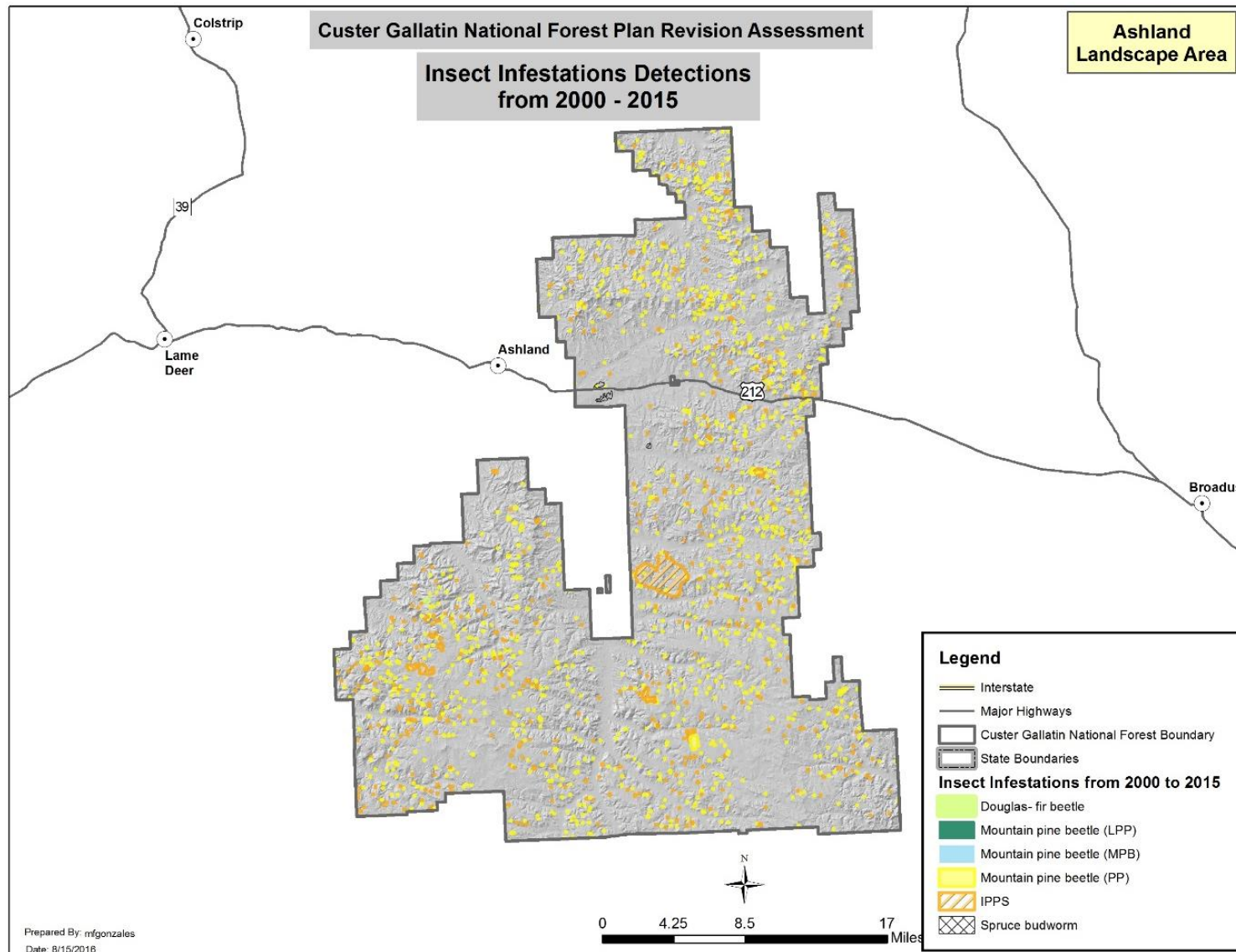




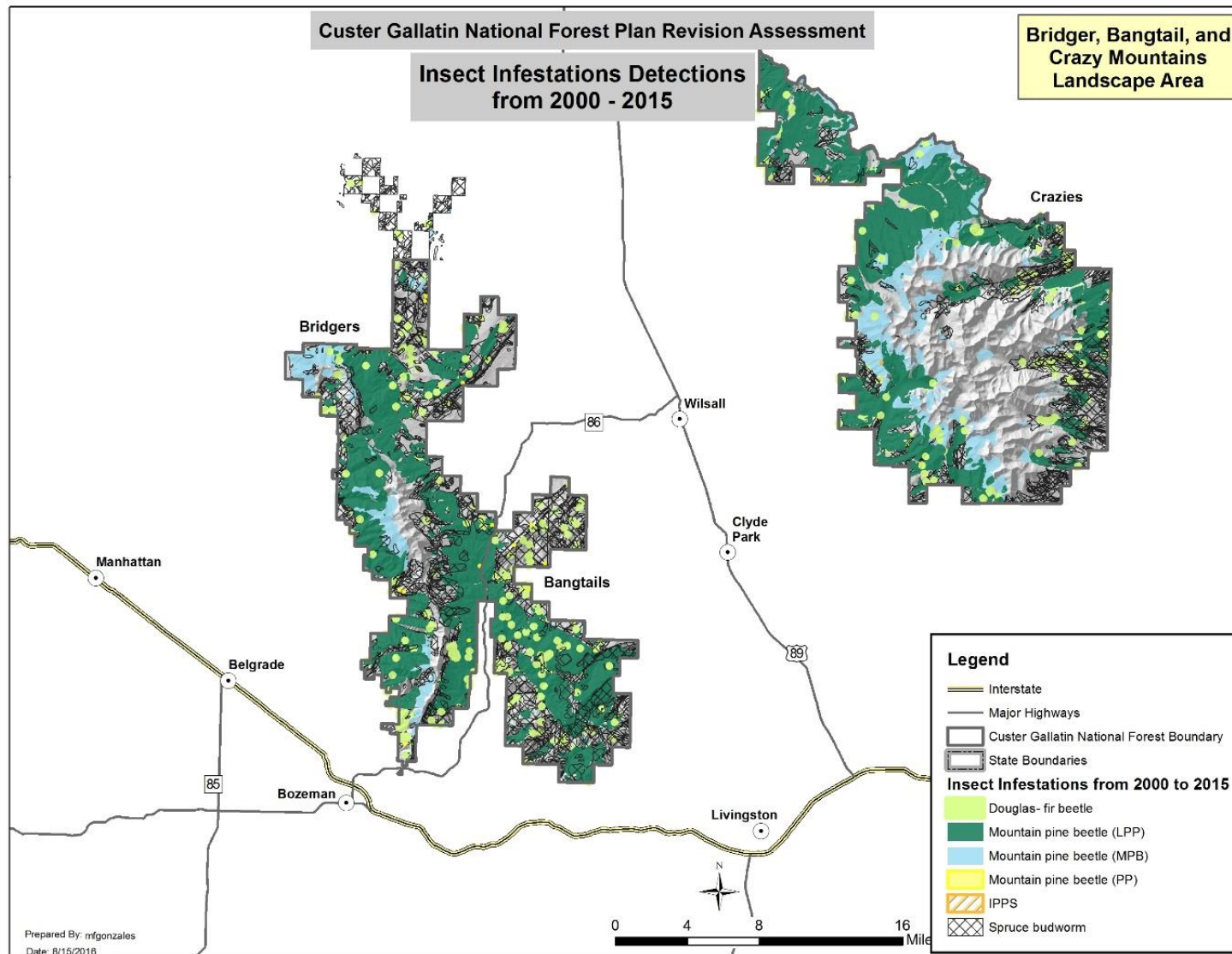
**Figure 82. Cumulative mountain pine beetle caused mortality from 2000 to 2015 on the Ashland analysis area, R1 USDA R1-FHP Aerial Detection Surveys**



**Figure 83. Cumulative mountain pine beetle caused mortality from 2000 to 2015 on the Sioux analysis area, R1 USDA R1-FHP Aerial Detection Surveys**



**Figure 84. Cumulative insects of concern from 2000 to 2015 on the Ashland analysis area, R1 USDA R1-FHP Aerial Detection Surveys**



**Figure 85. Cumulative insects of concern from 2000 to 2015 on the Bridgers, Bangtails, and Crazies analysis area, R1 USDA R1-FHP Aerial Detection Surveys**



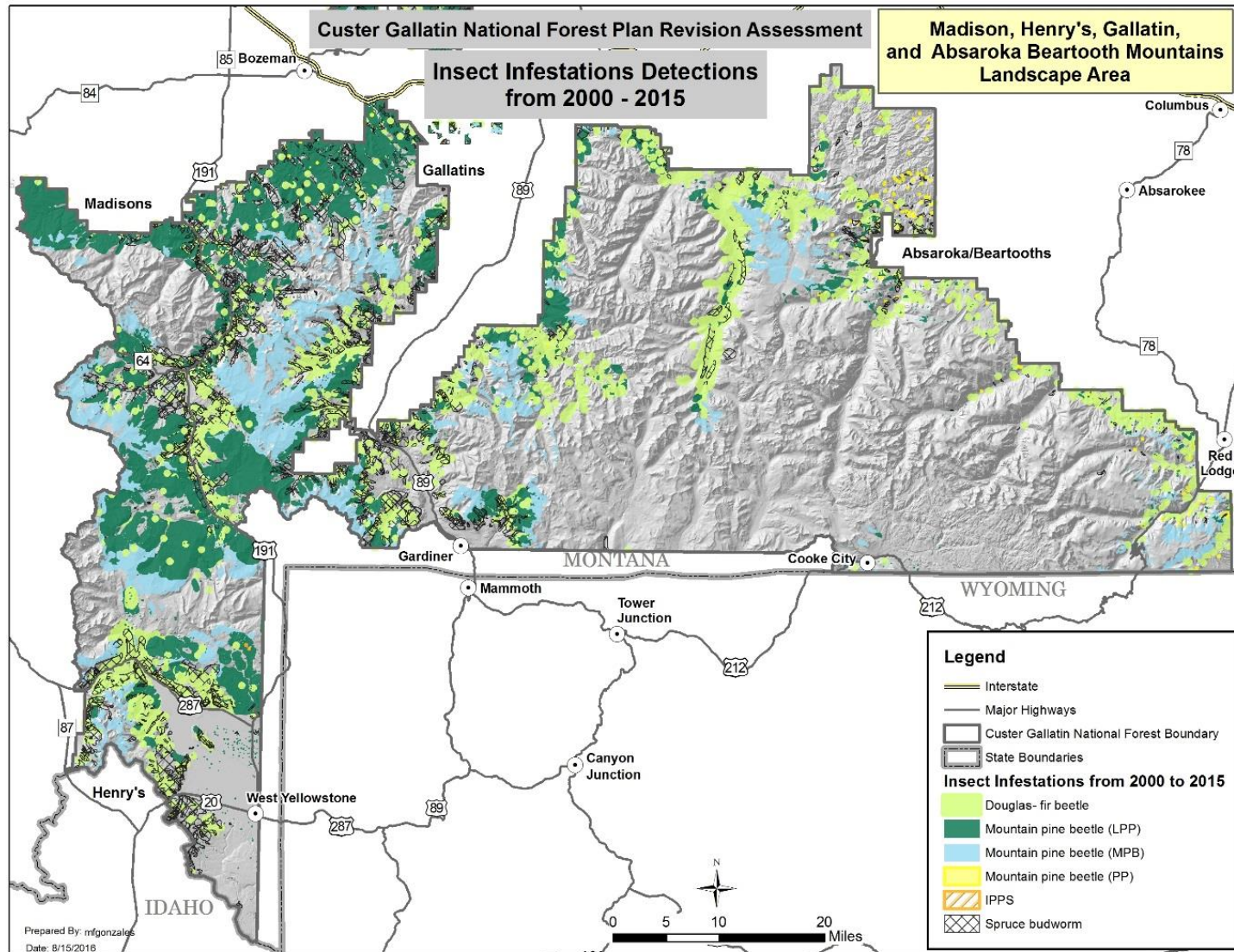


Figure 86. Cumulative insects of concern from 2000 to 2015 on the Madison, Henrys Lake, Gallatin, Absaroka and Beartooth Mtns analysis area, R1 USDA R1-FHP Aerial Detection Surveys



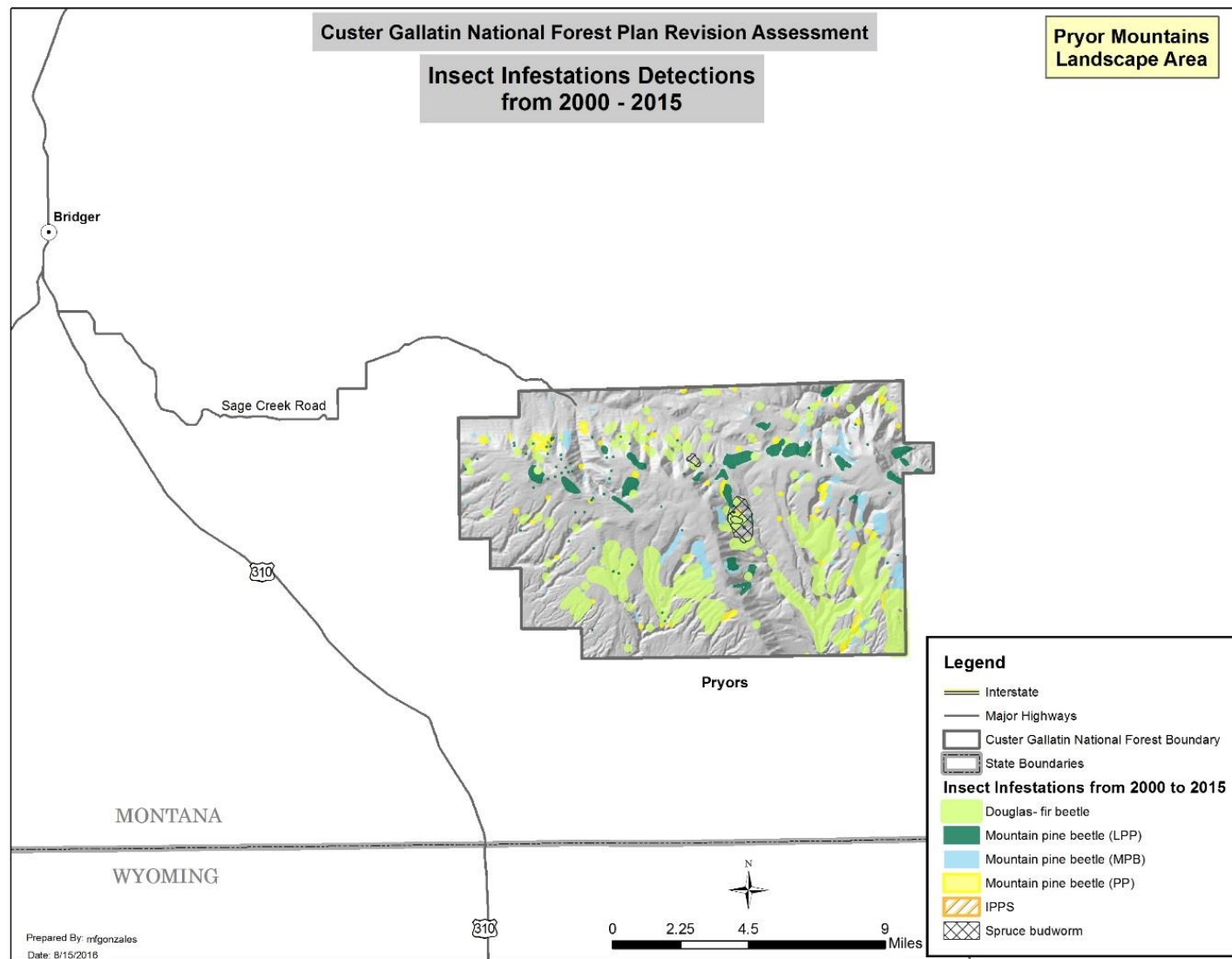


Figure 87. Cumulative insects of concern from 2000 to 2015 on the Pryors analysis area, R1 USDA R1-FHP Aerial Detection Surveys

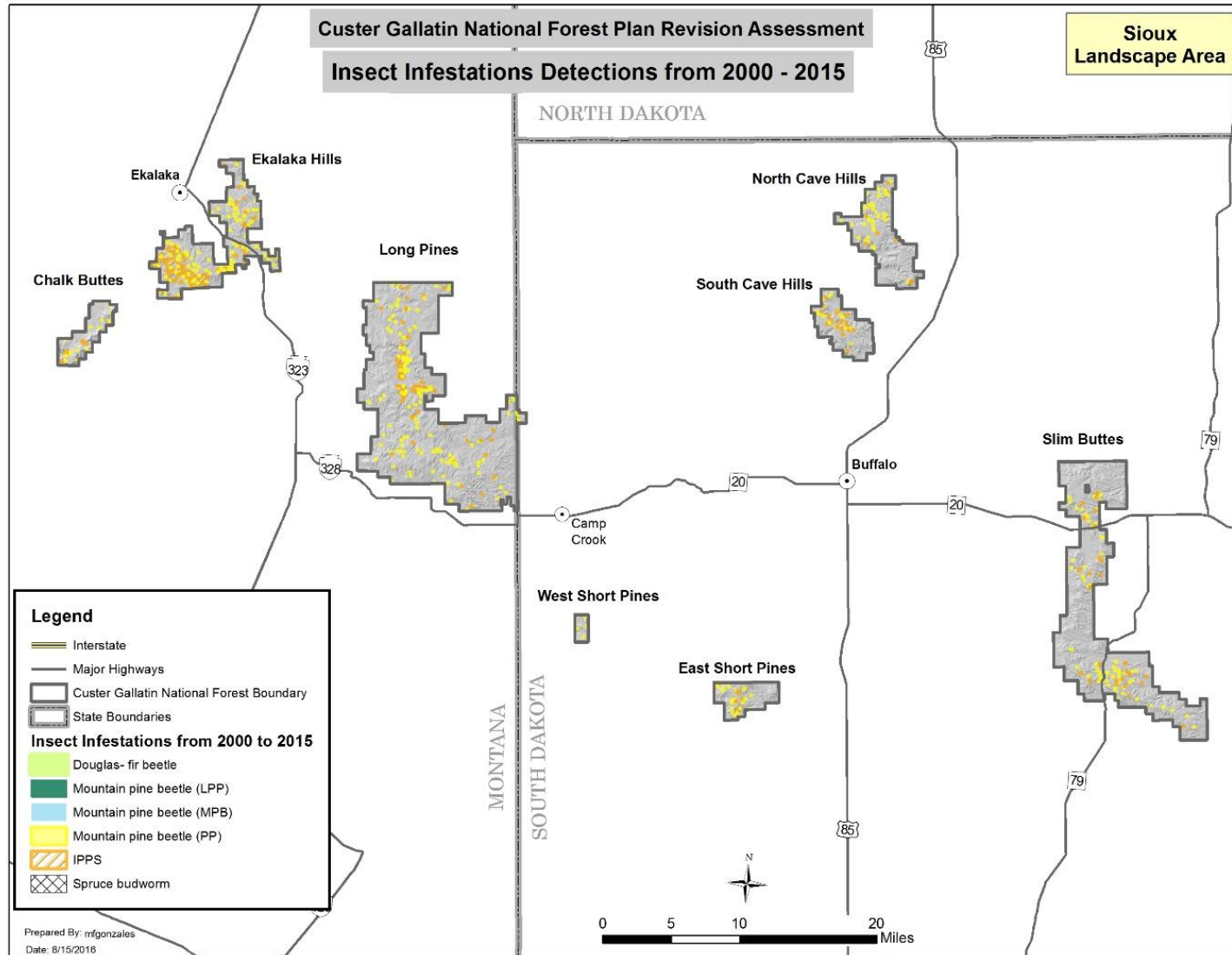


Figure 88. Cumulative insects of concern from 2000 to 2015 on the Sioux analysis area, R1 USDA R1-FHP Aerial Detection Surveys

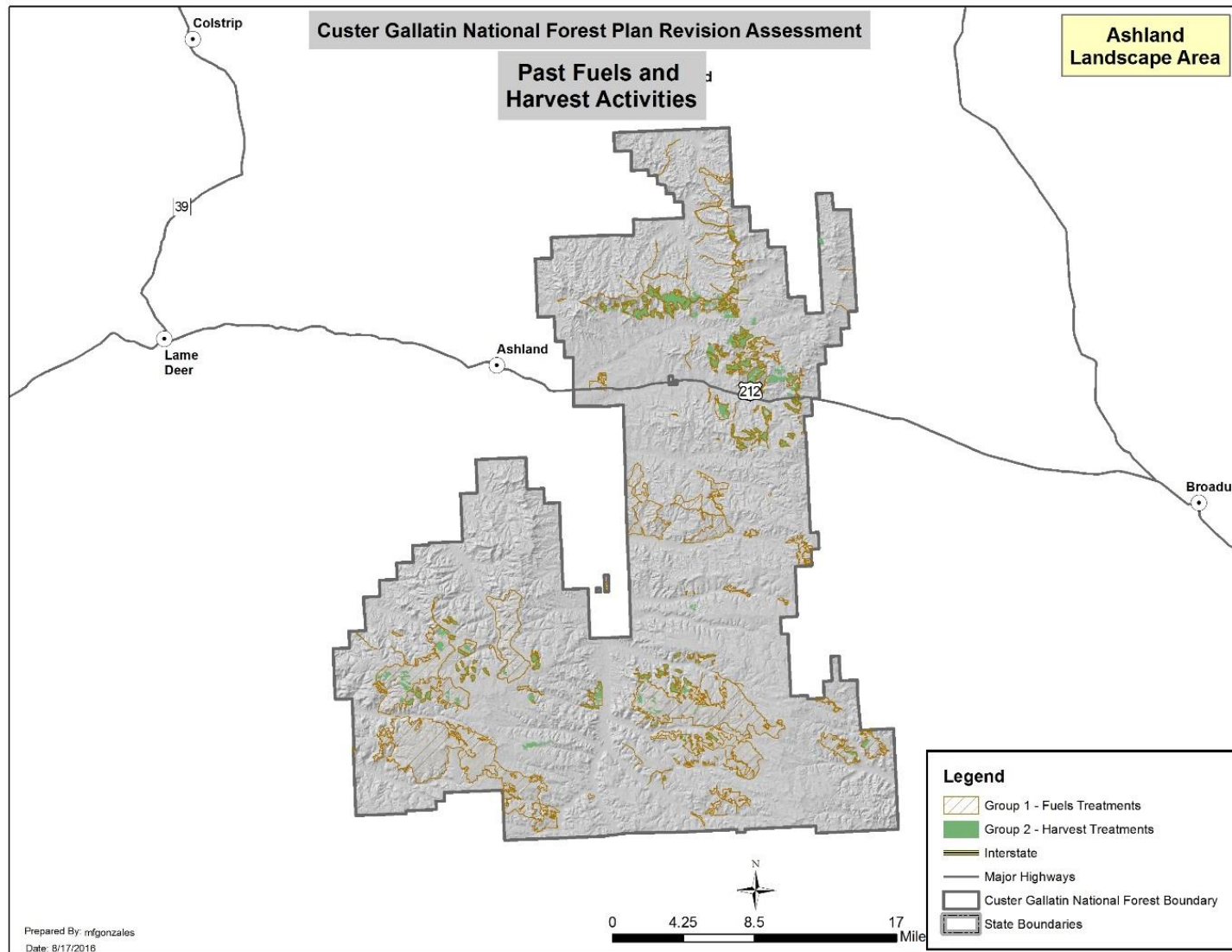
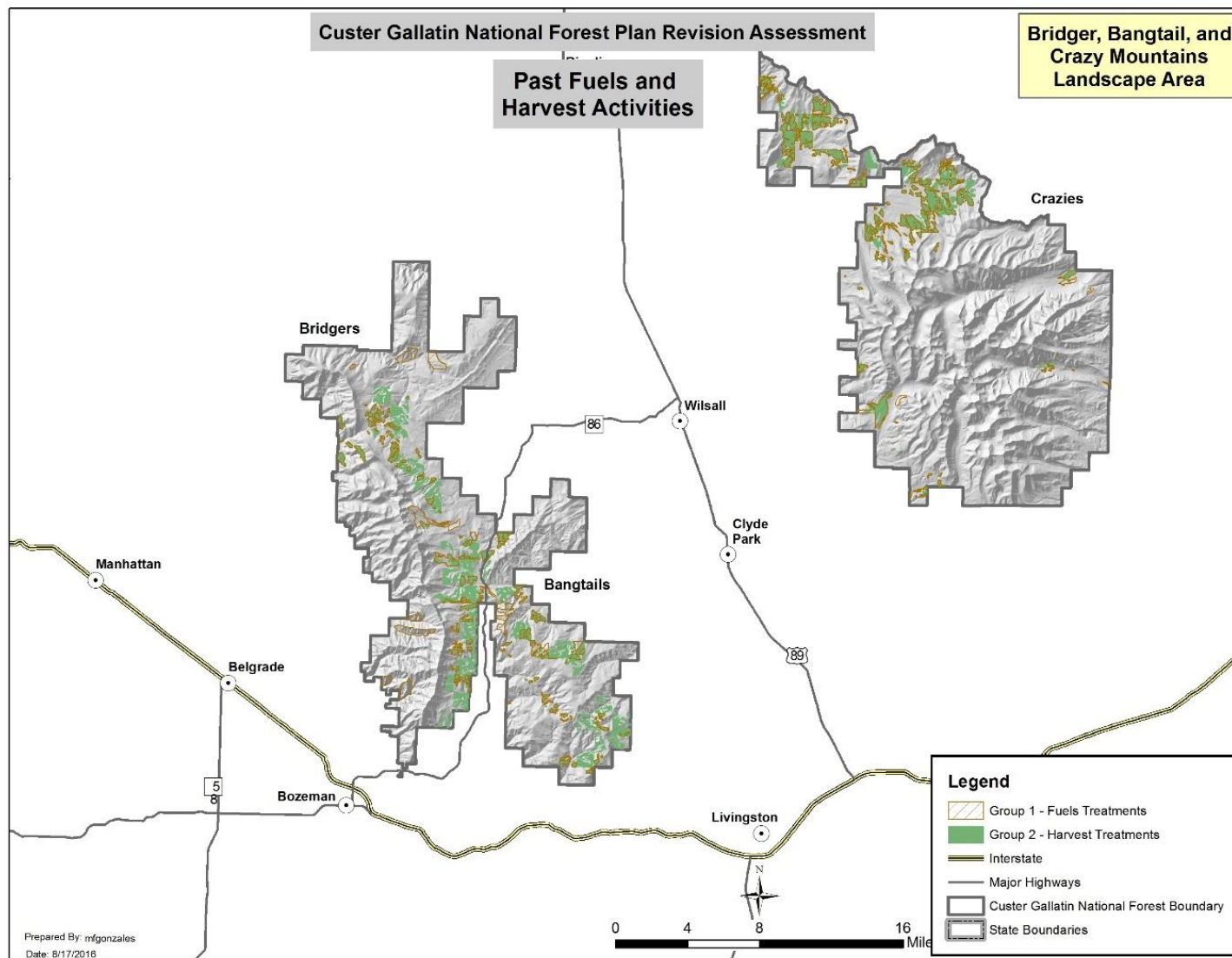


Figure 89. Fuels and harvest treatments on the Ashland analysis area, R1 USDA R1-FHP Aerial Detection Surveys



**Figure 90. Fuels and harvest treatments on the Bridgers, Bangtails, and Crazies analysis area, R1 USDA R1-FHP Aerial Detection Surveys**



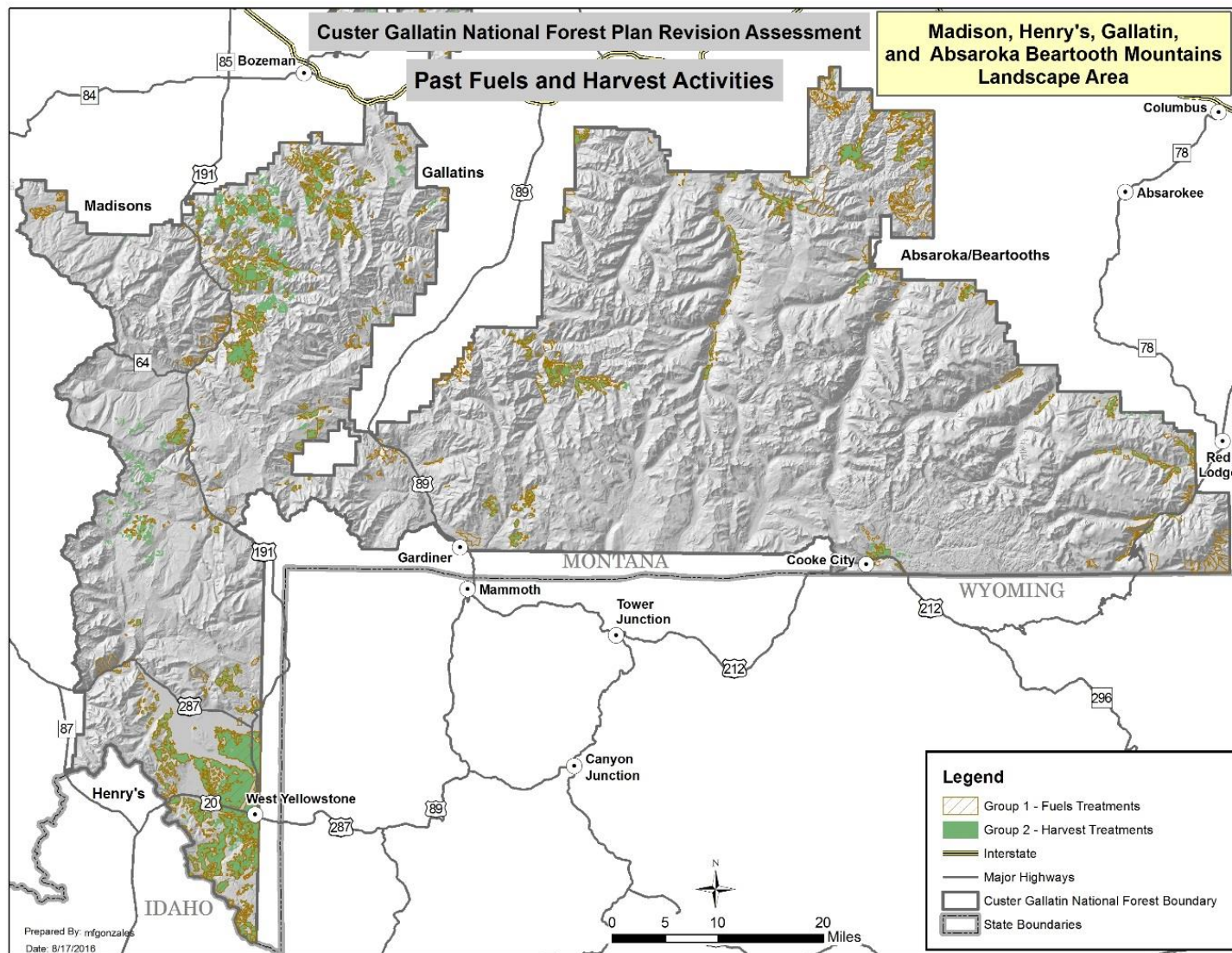


Figure 91. Fuels and harvest treatments on the Madison, Henrys Lake, Gallatin, Absaroka and Beartooth Mtns analysis area, R1 USDA R1-FHP Aerial Detection Surveys

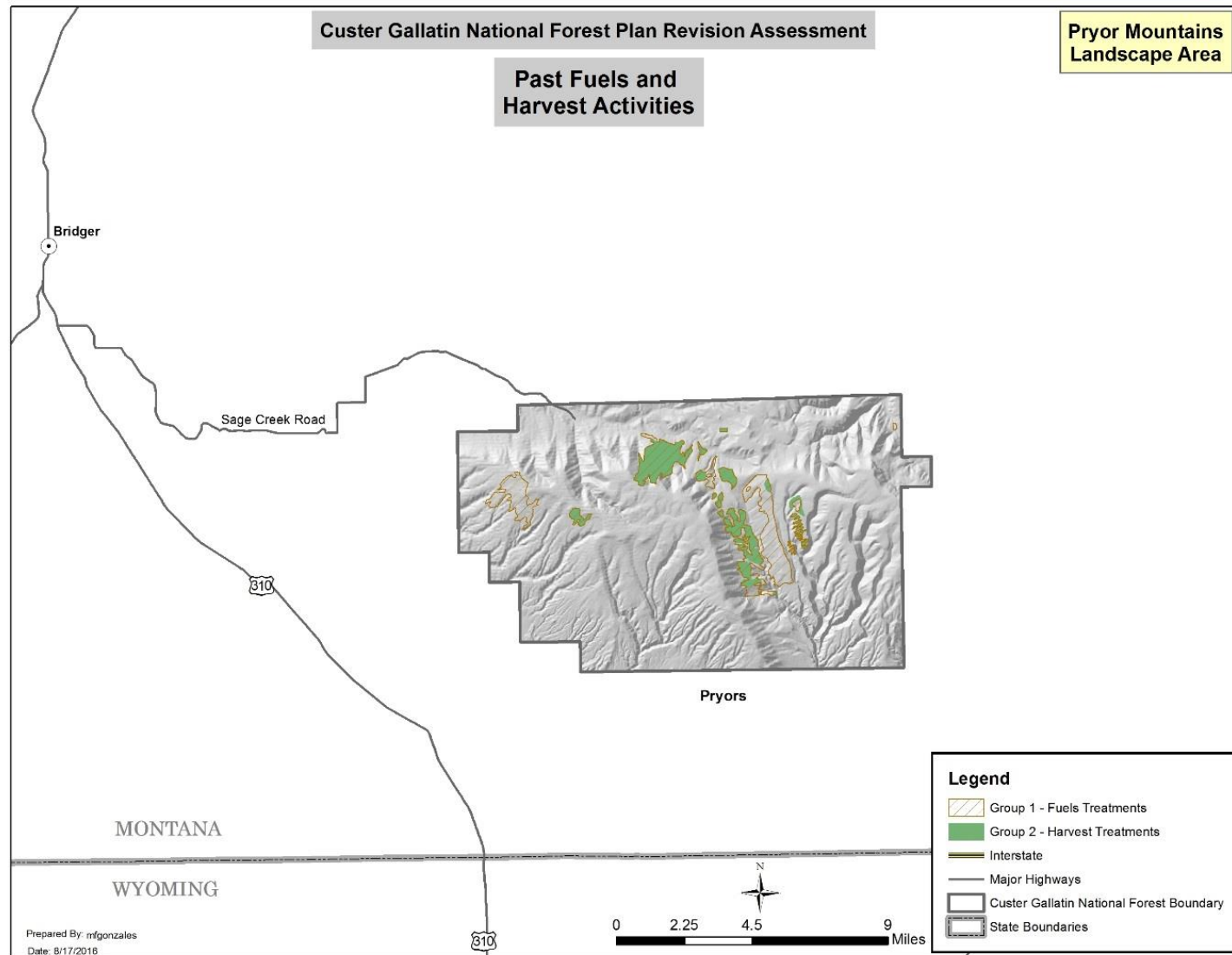


Figure 92. Fuels and harvest treatments on the Pryors analysis area, R1 USDA R1-FHP Aerial Detection Surveys

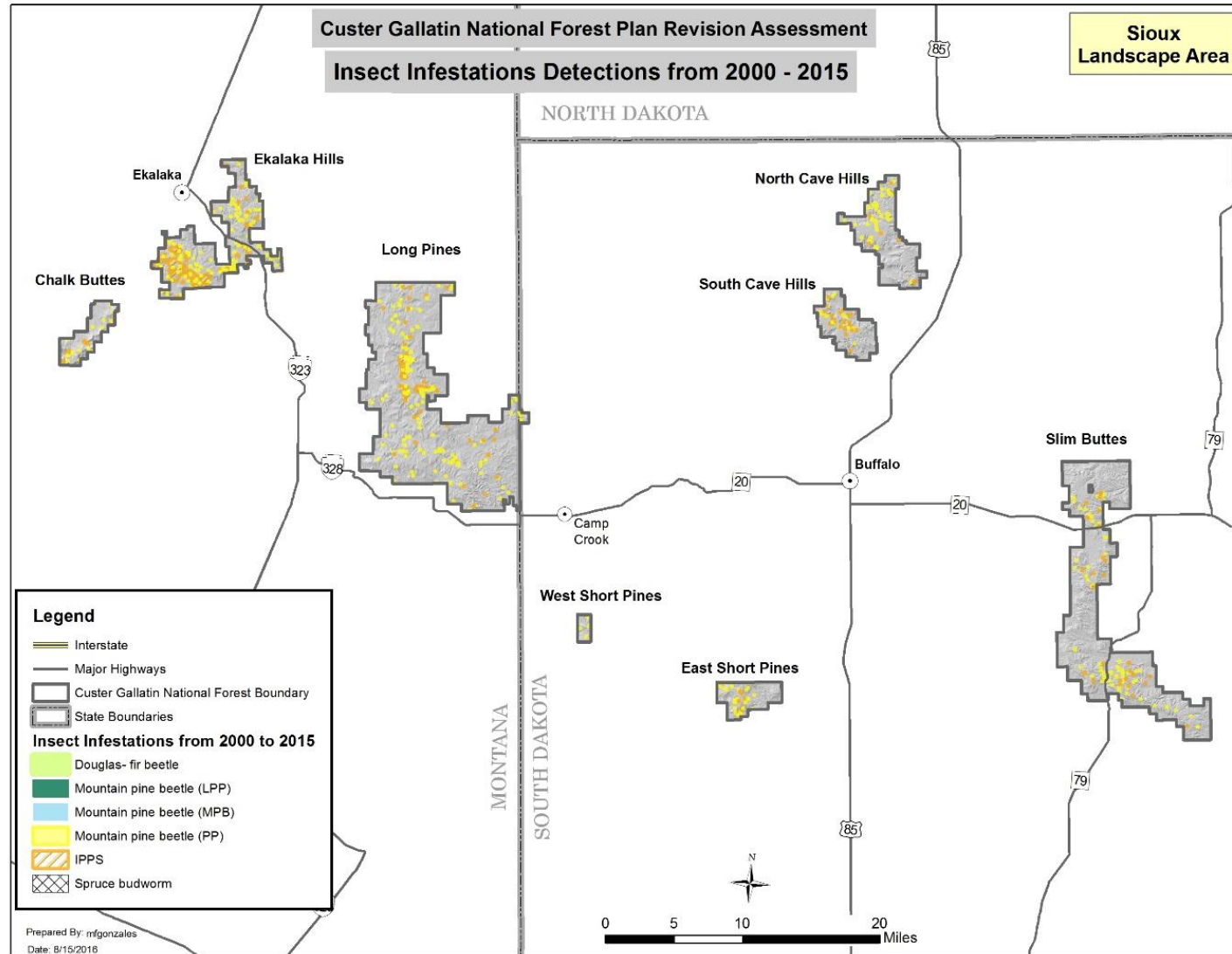


Figure 93. Fuels and harvest treatments on the Sioux analysis area, R1 USDA R1-FHP Aerial Detection Surveys

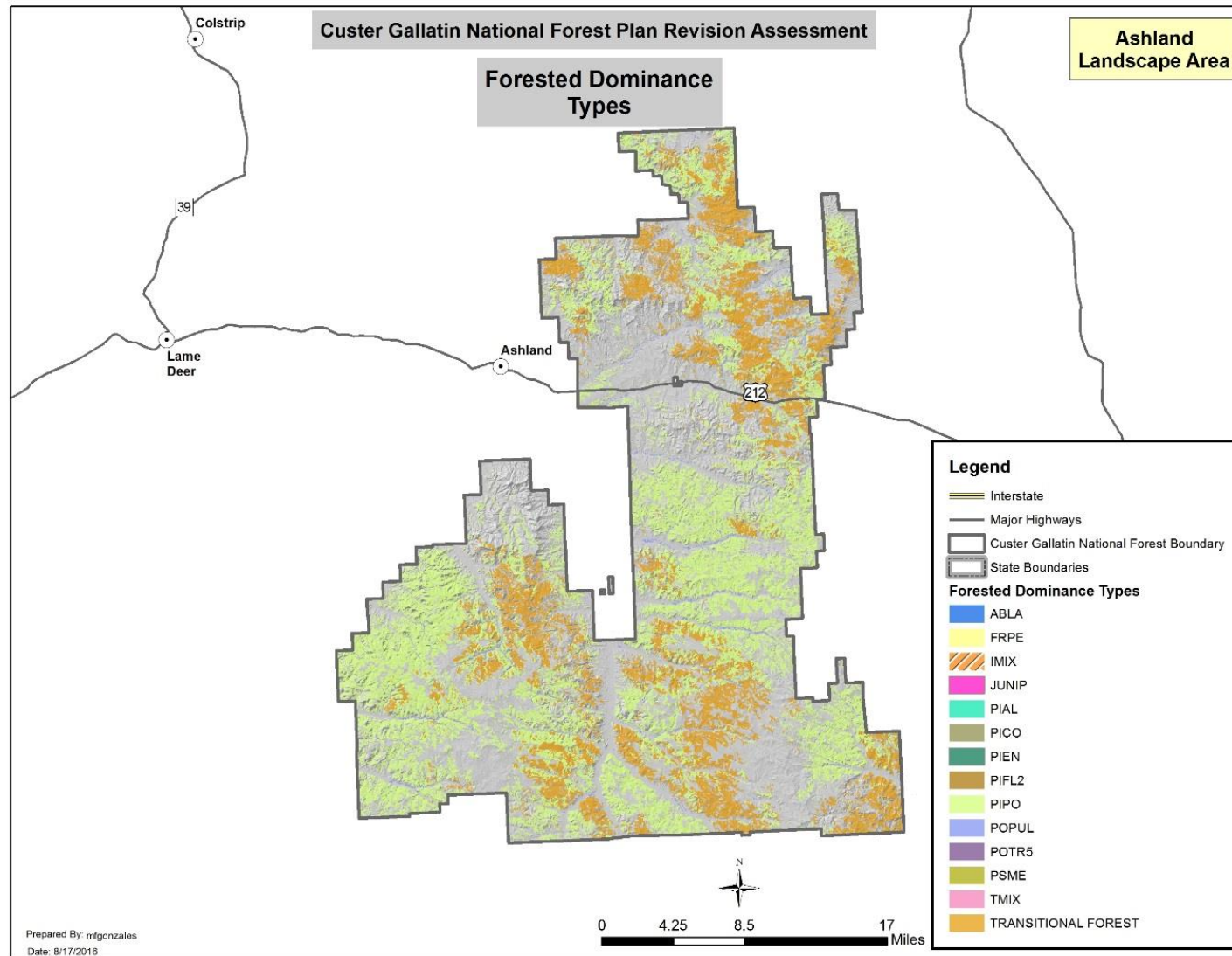


Figure 94. Dominance types on the Ashland analysis area, VMap



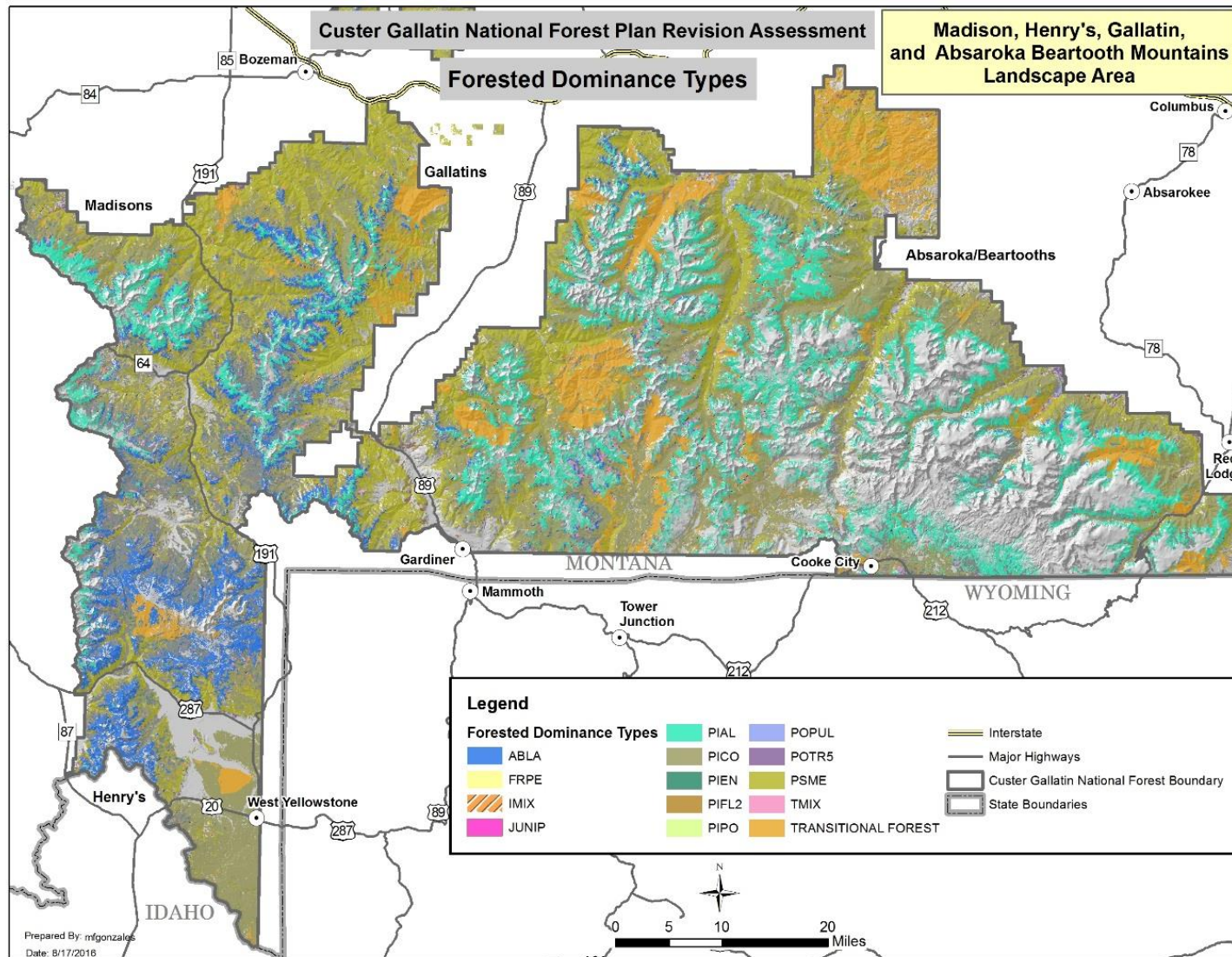


Figure 95. Dominance types on the Madison, Henrys Lake, Gallatin, Absaroka and Beartooth Mtns analysis area, VMap

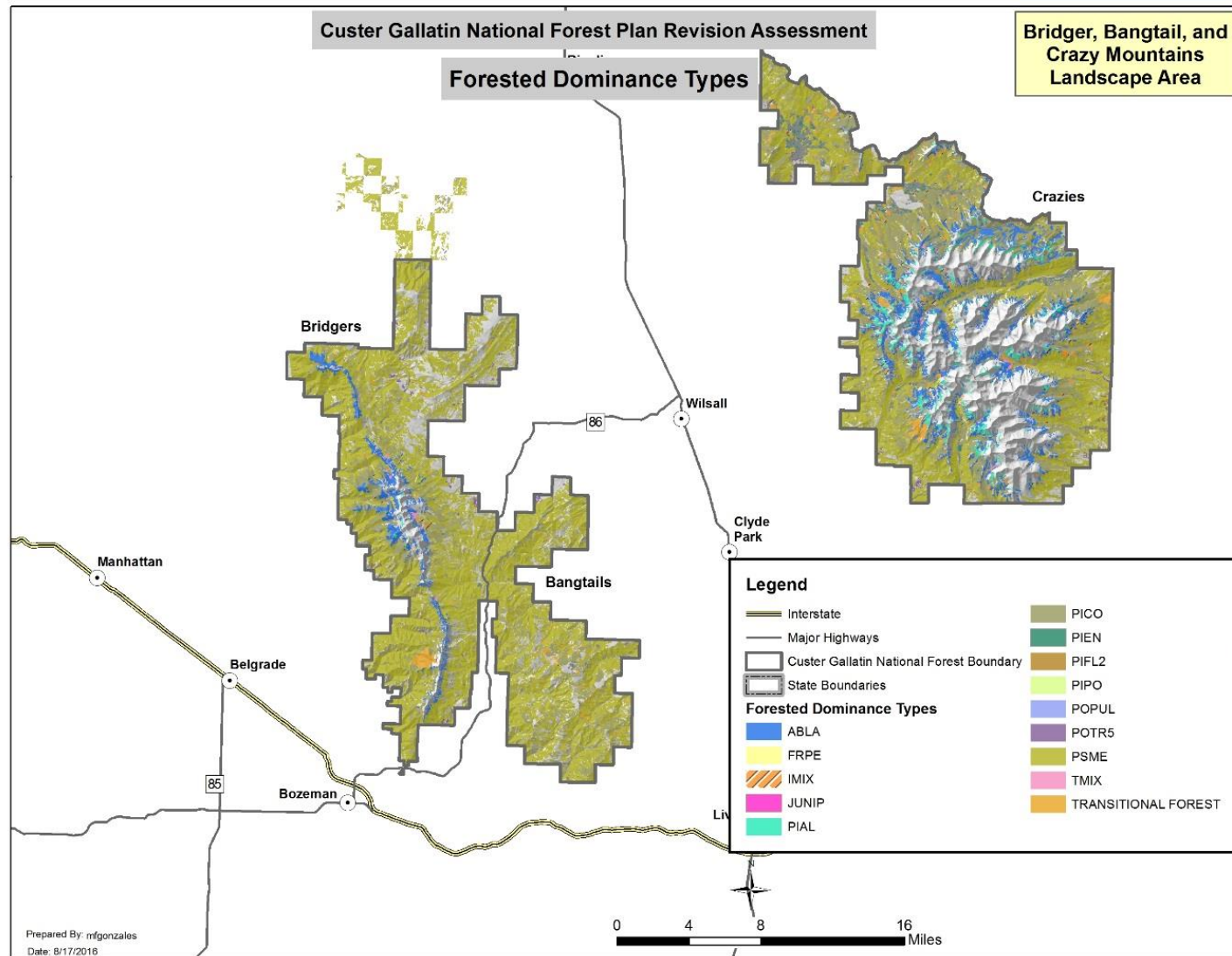


Figure 96. Dominance types on the Bridgers, Bangtails, and Crazies analysis area, VMap

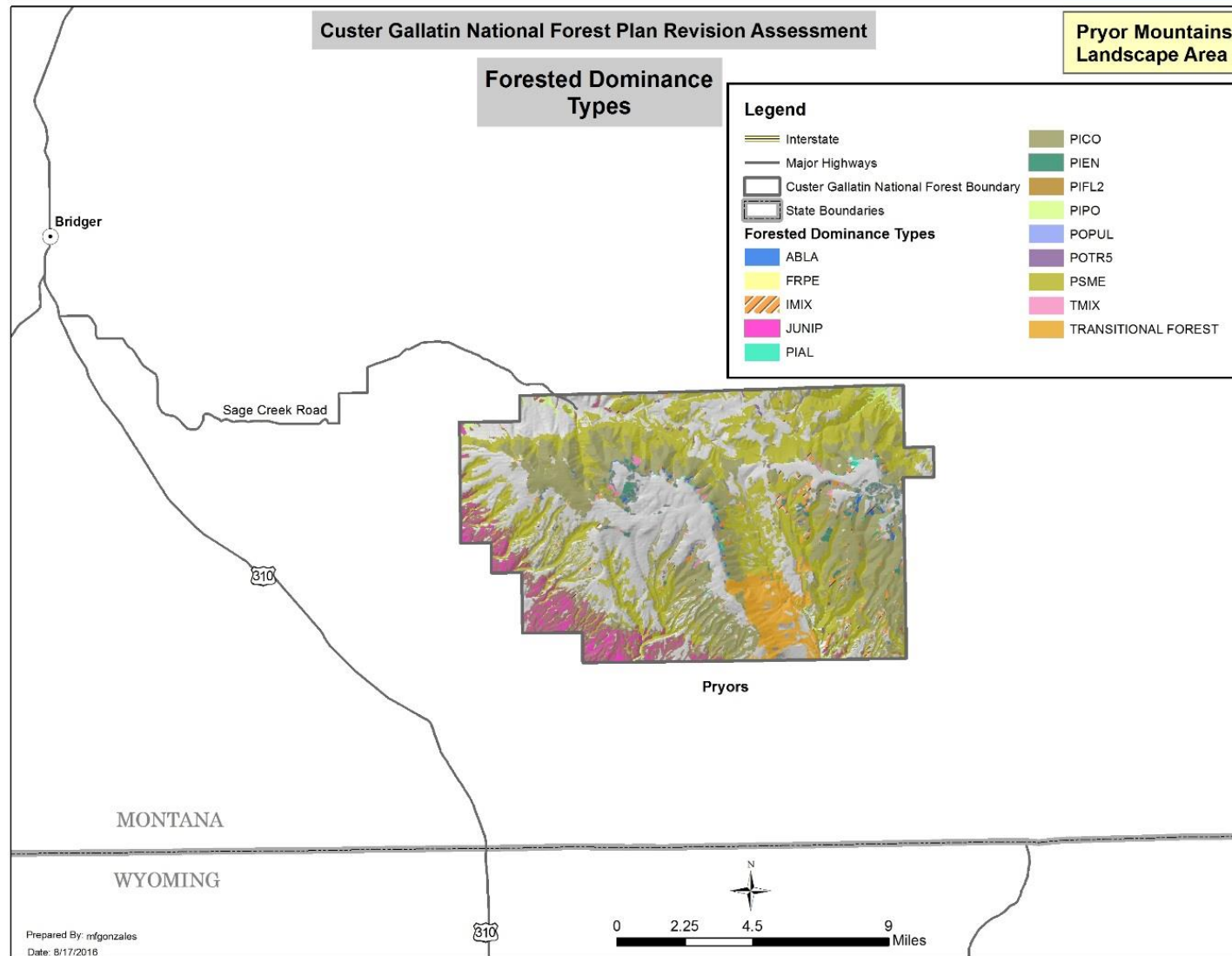


Figure 97. Dominance types on the Pryors analysis area, VMap

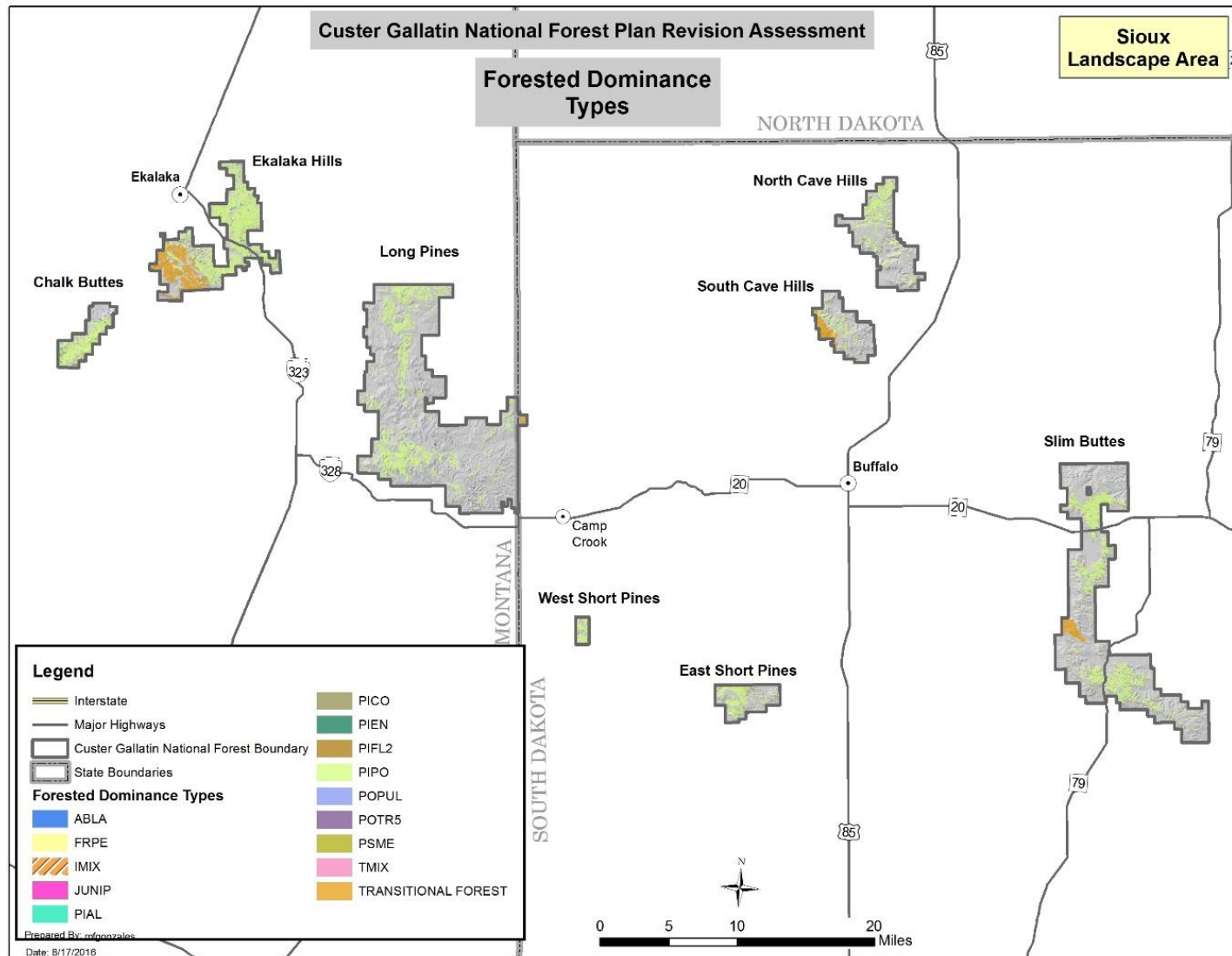


Figure 98. Dominance types on the Sioux analysis area, VMap



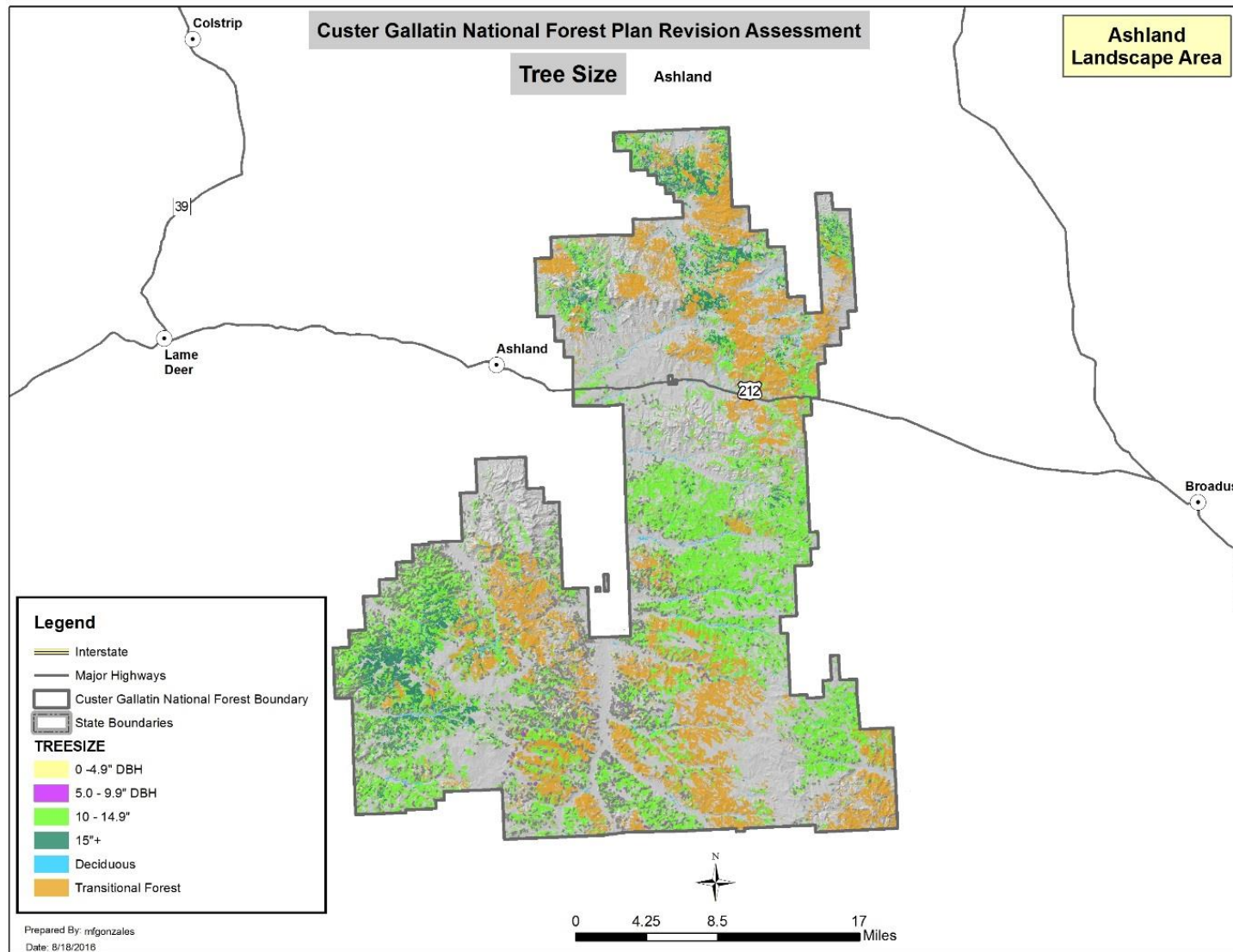


Figure 99. Tree size class and transitional forest on the Ashland analysis area, VMap

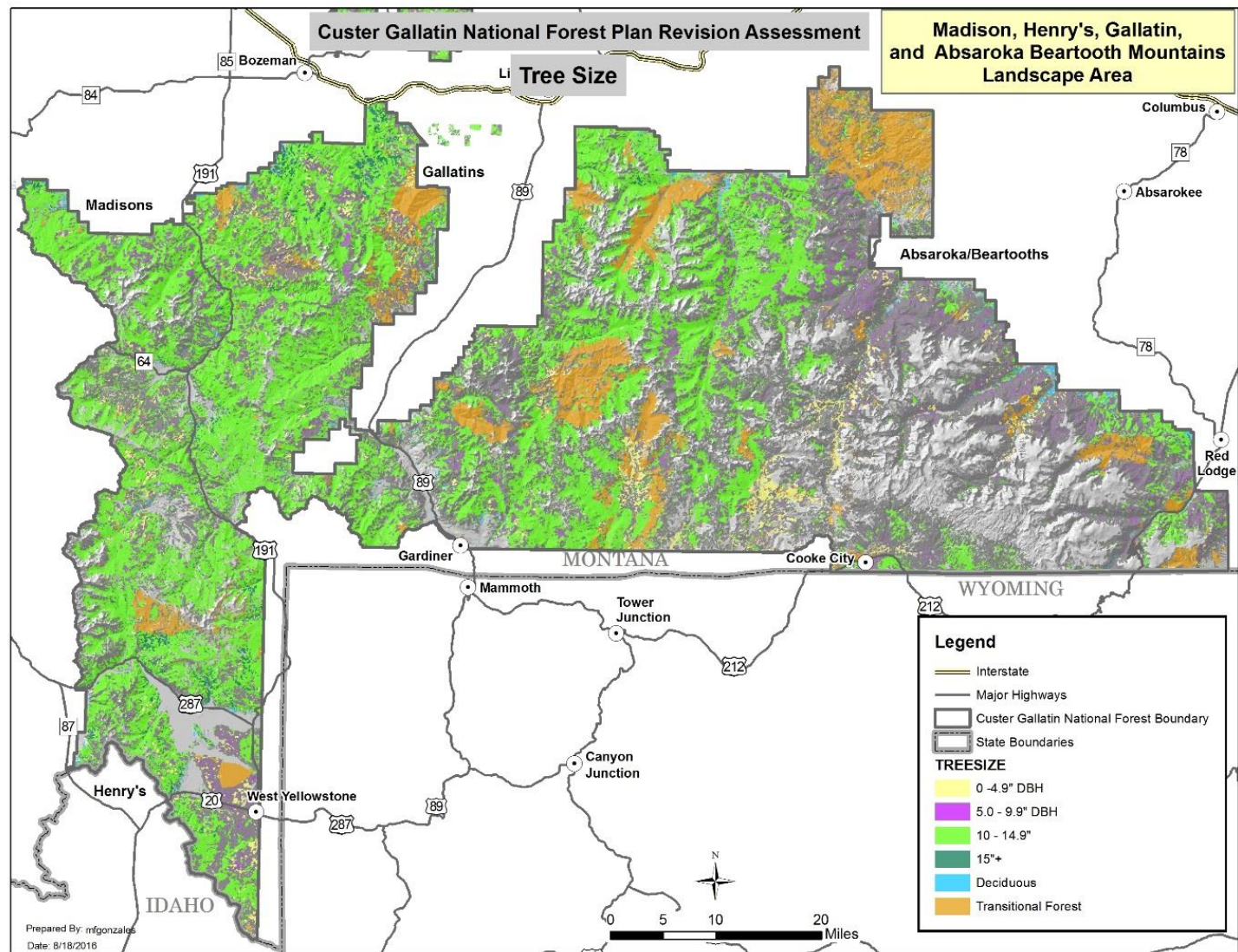


Figure 100. Tree size class and transitional forest on the Madison, Henrys Lake, Gallatin, Absaroka and Beartooth Mtns analysis area, VMap

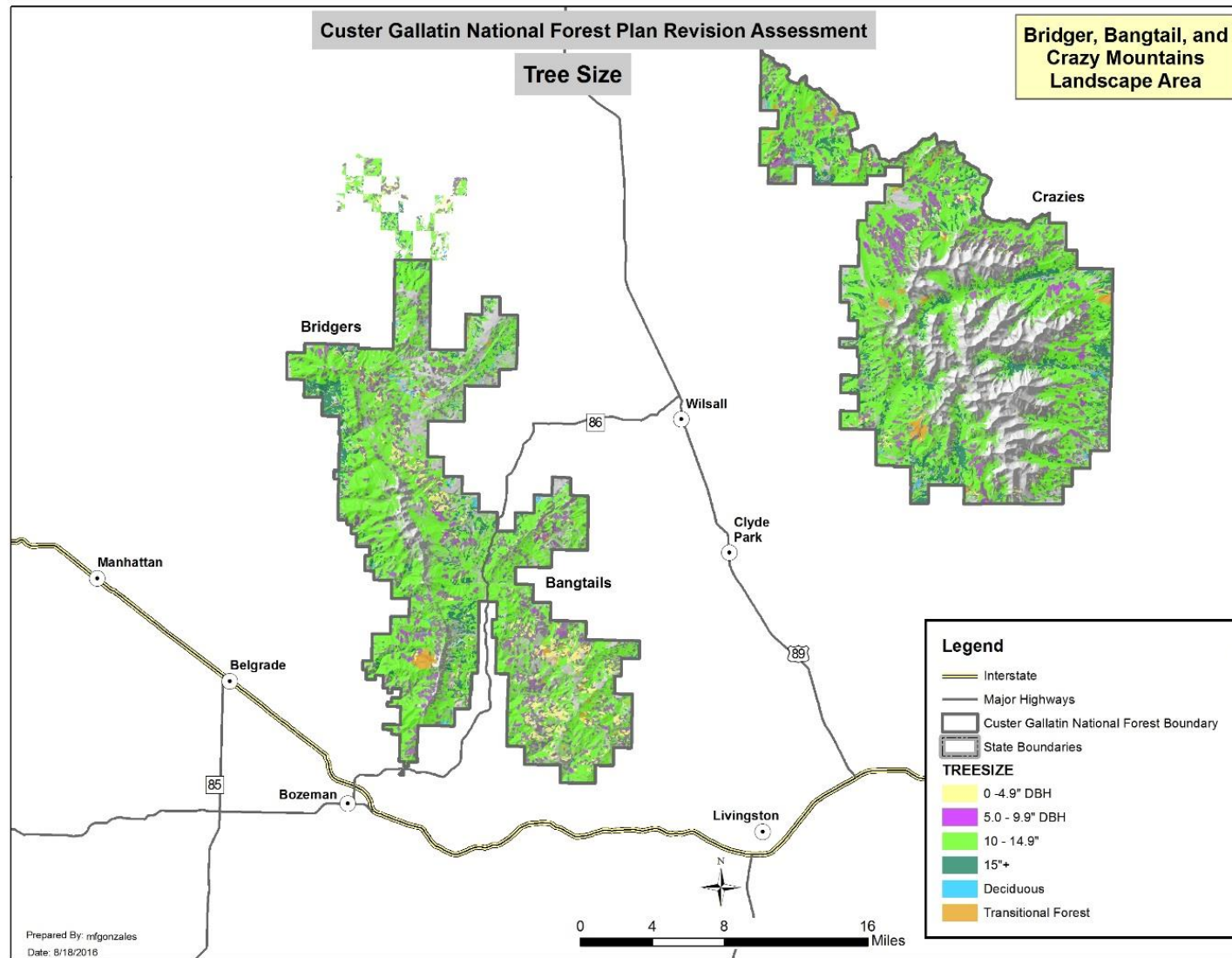


Figure 101. Tree size class and transitional forest on the Bridgers, Bangtails, Crazies analysis area, VMap



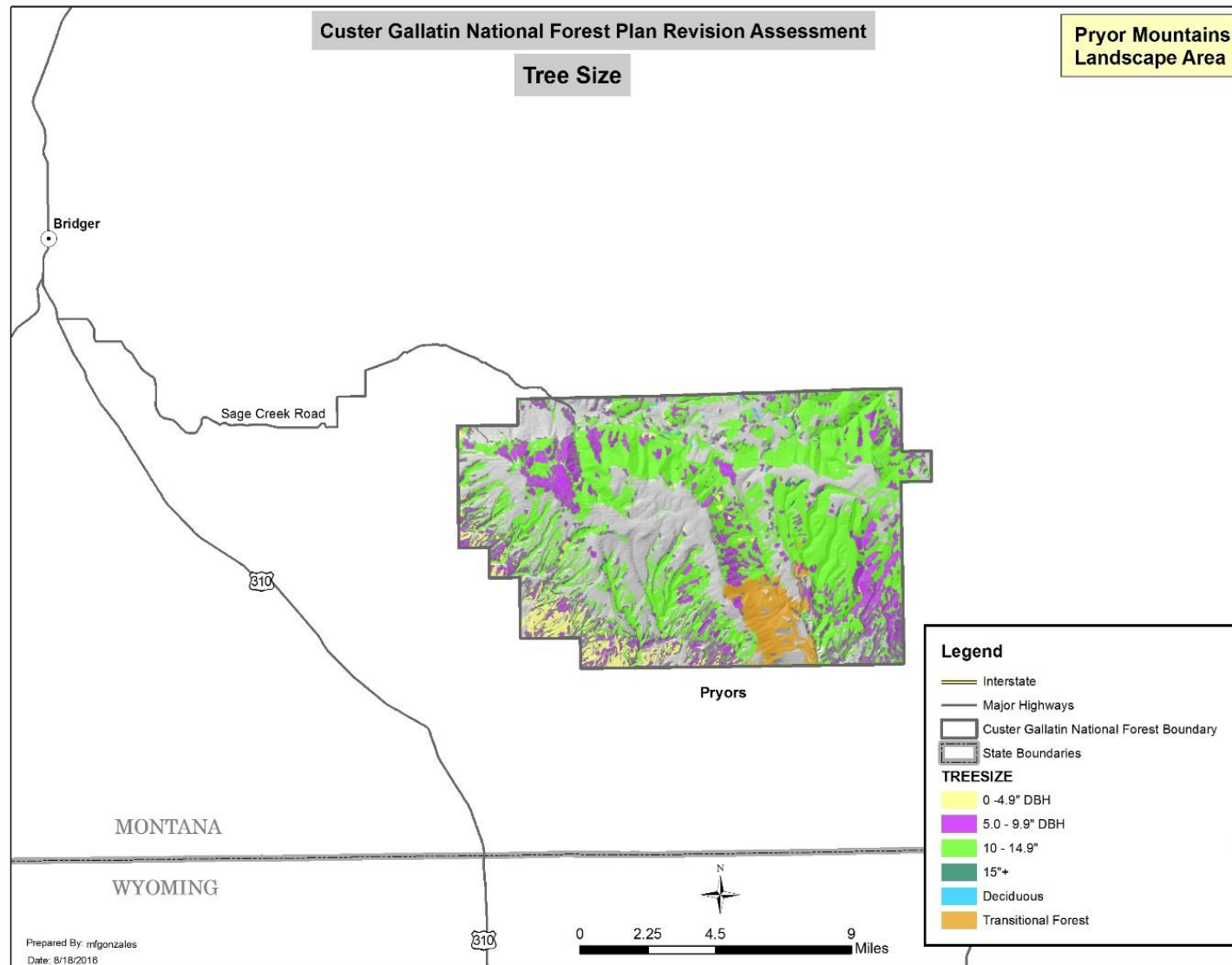


Figure 102. Tree size class and transitional forest on the Pryors analysis area, VMap



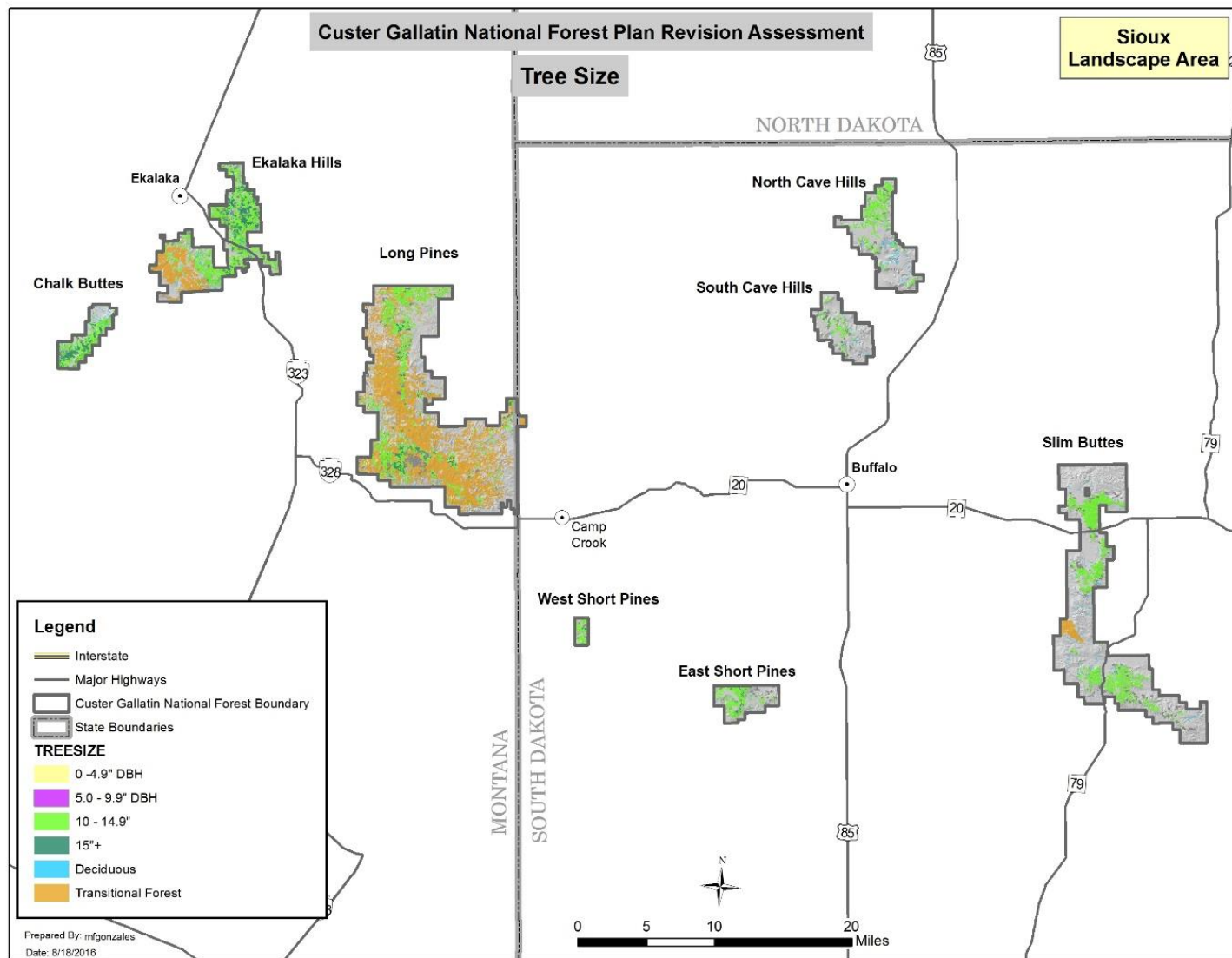


Figure 103. Tree size class and transitional forest on the Sioux analysis area, VMap

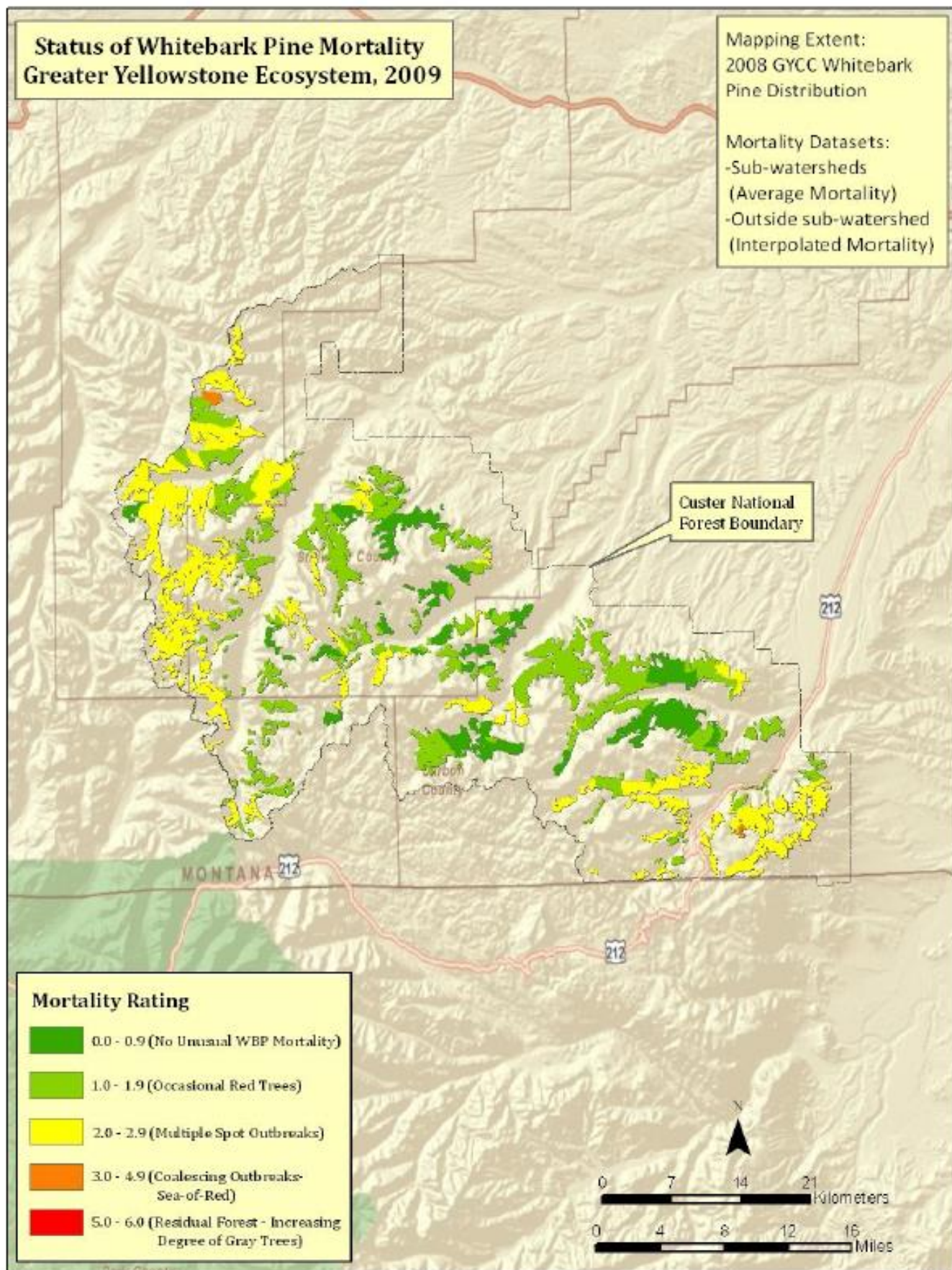


Figure 104. Custer NF GYWPC whitebark pine distribution mortality map (Macfarlane et al. 2010)



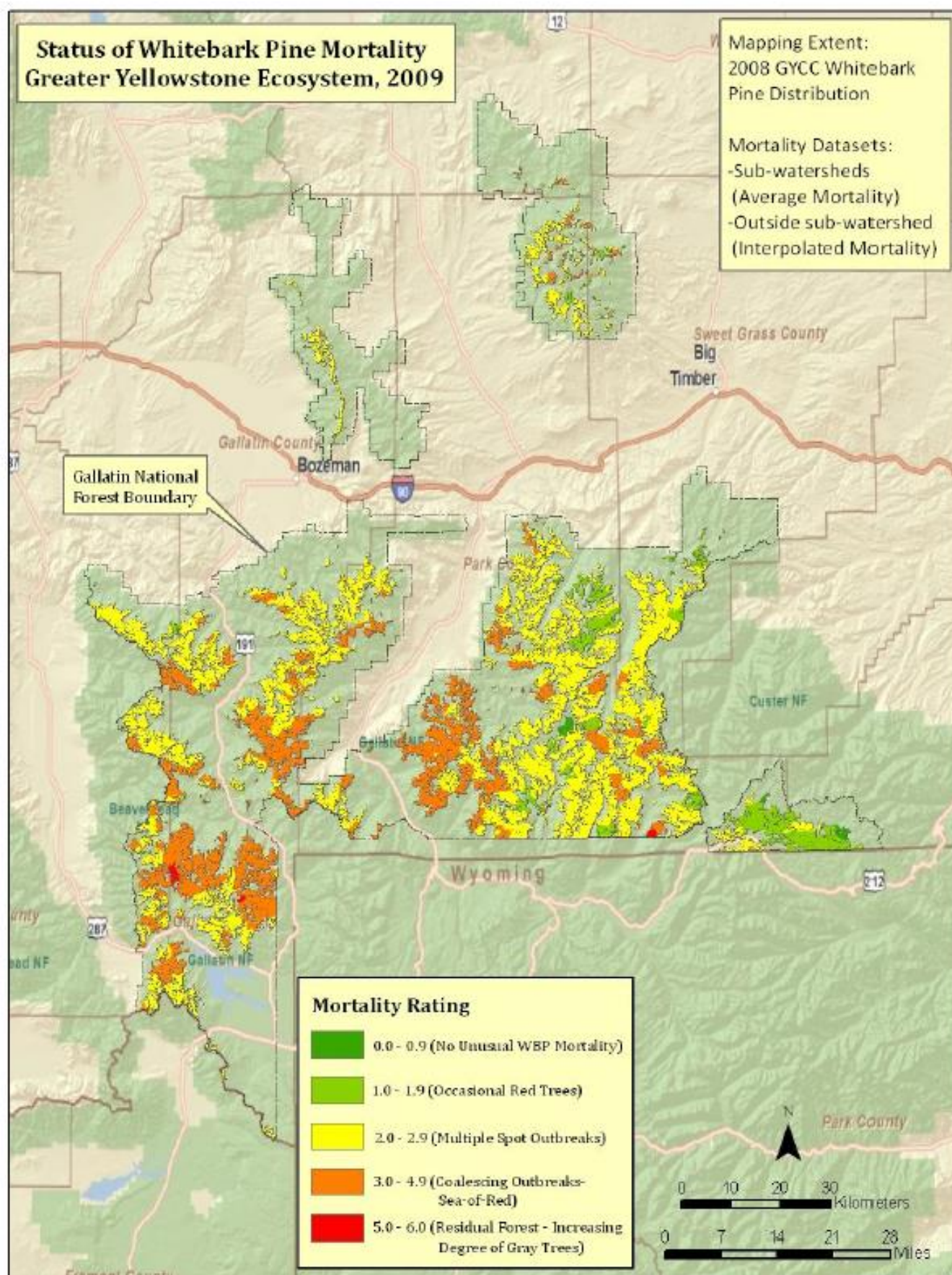


Figure 105. Gallatin NF GYWPC whitebark pine distribution mortality map (Macfarlane et al. 2010)

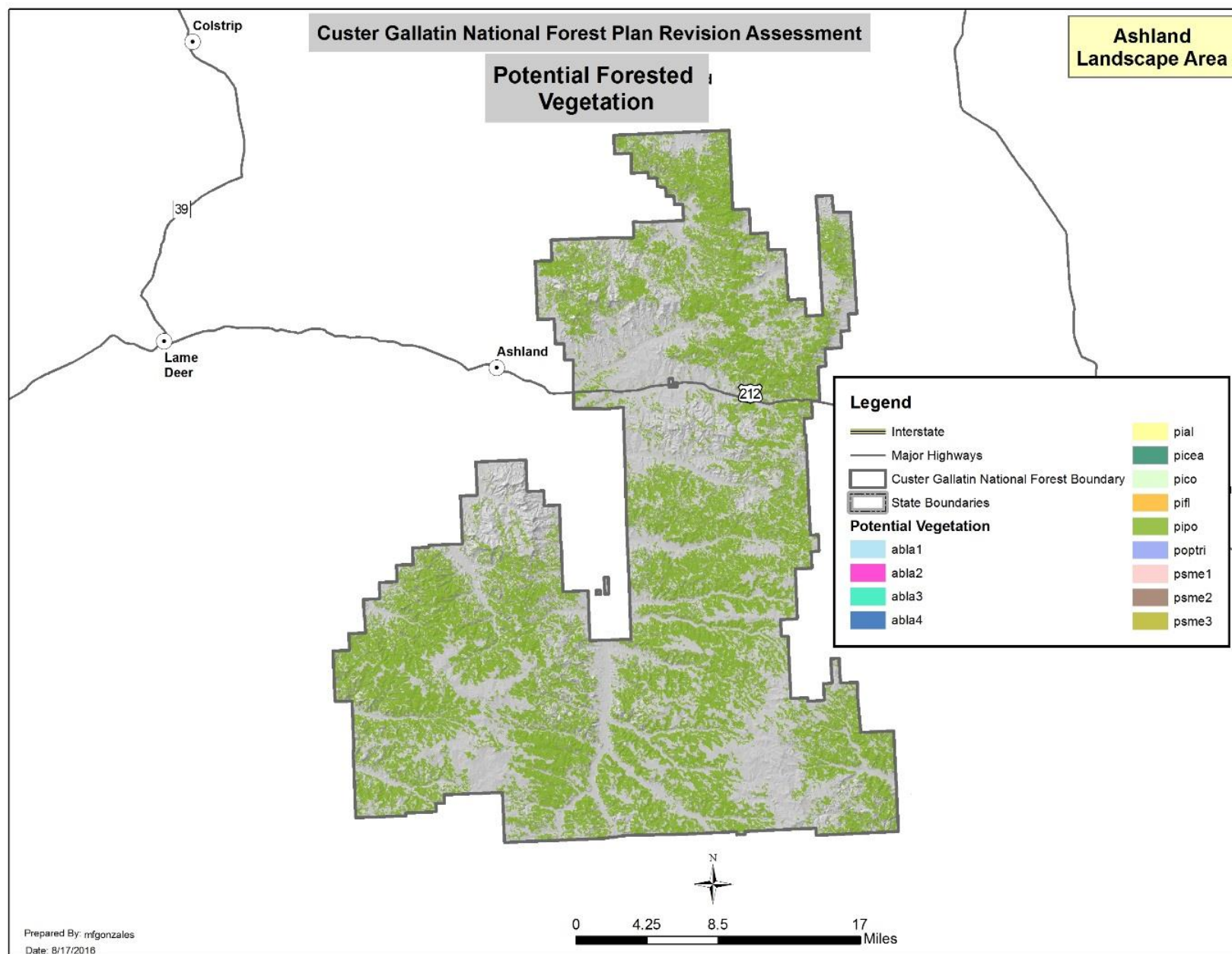


Figure 106. Potential forested vegetation for the Ashland analysis area, VMap – Jones PVT



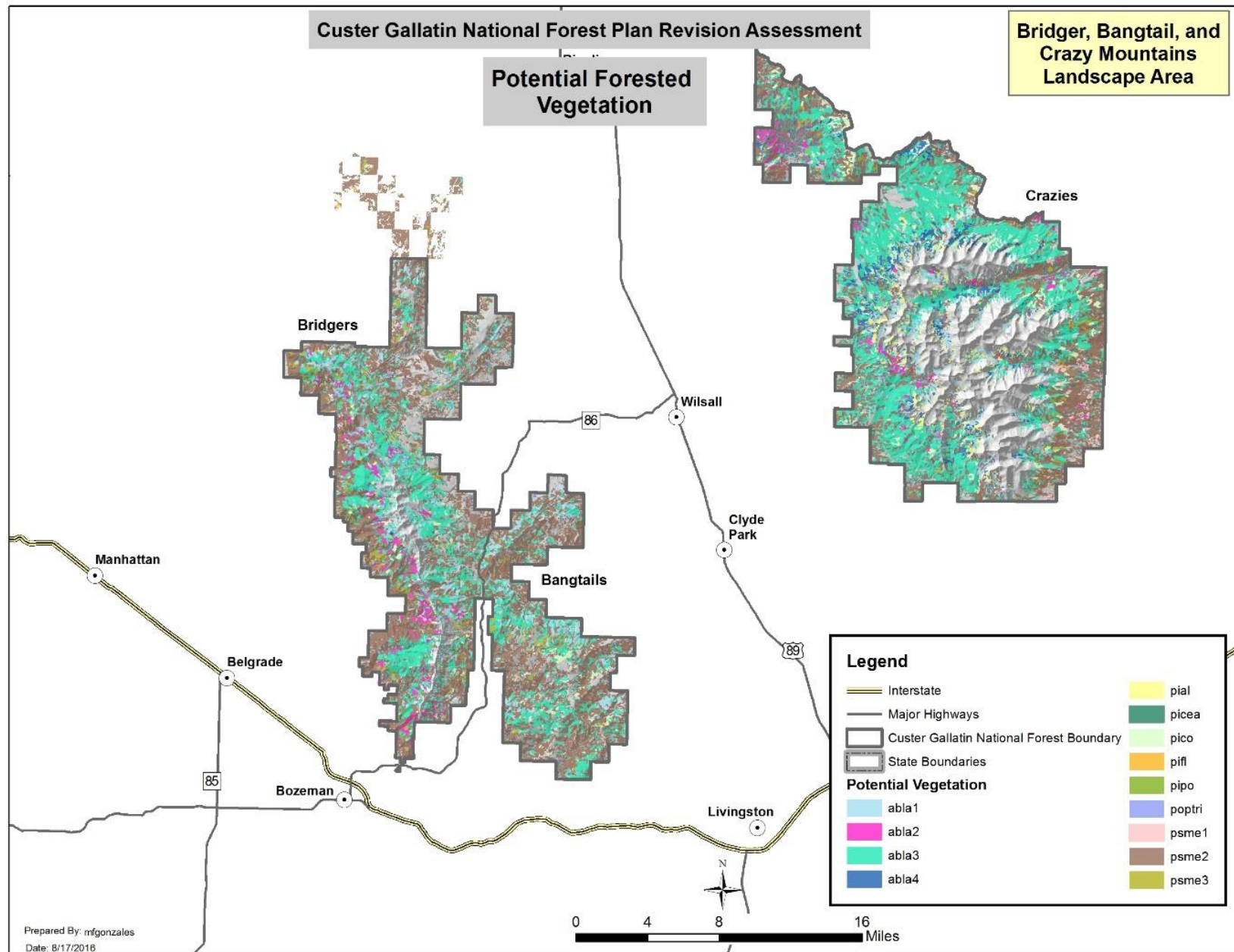


Figure 107. Potential forested vegetation for the Bridgers, Bangtails, Crazy Mountains analysis area, VMap – Jones PVT

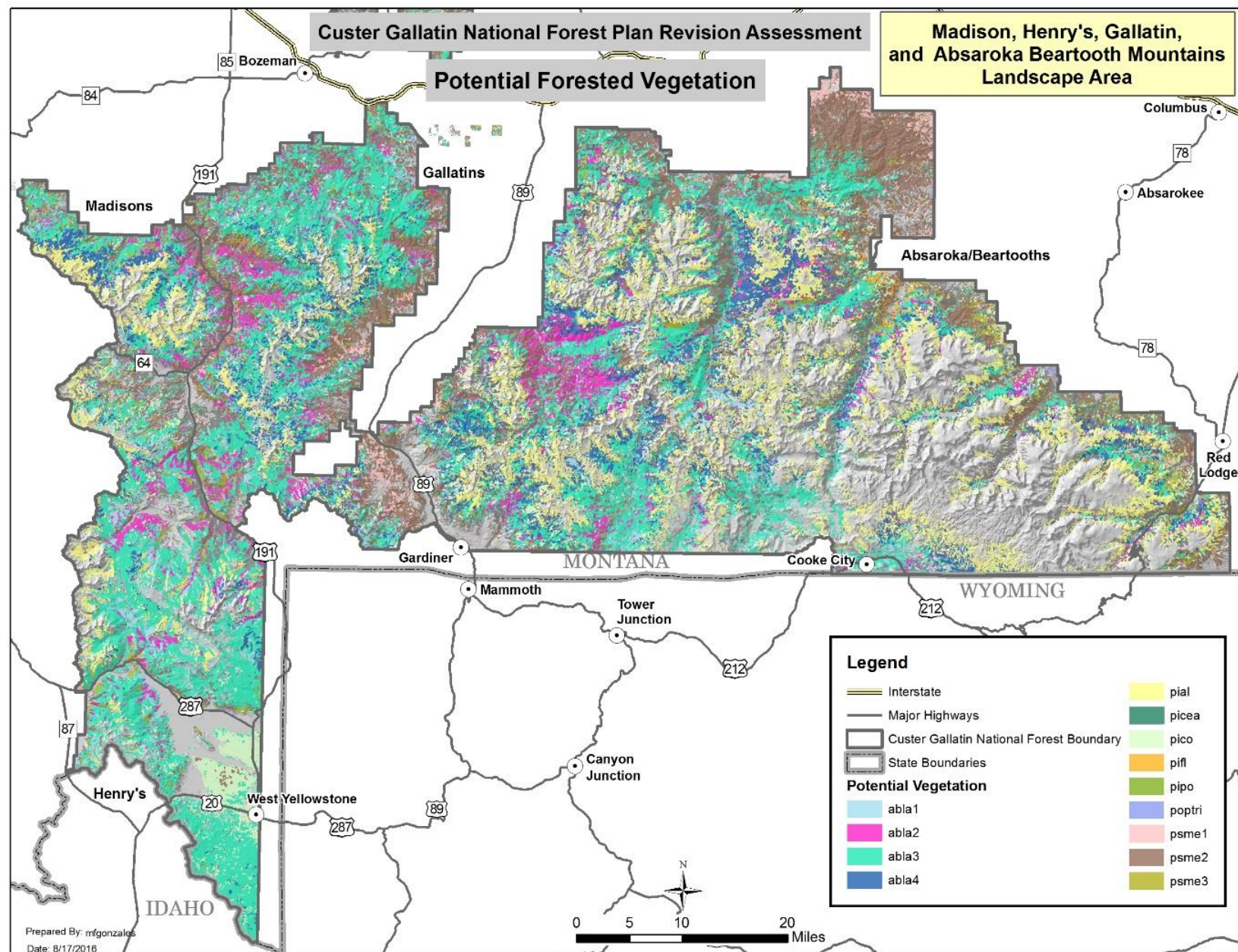


Figure 108. Potential forested vegetation for the Madison, Henrys Lake, Gallatin, Absaroka and Beartooth Mtns analysis area, VMap – Jones PVT.



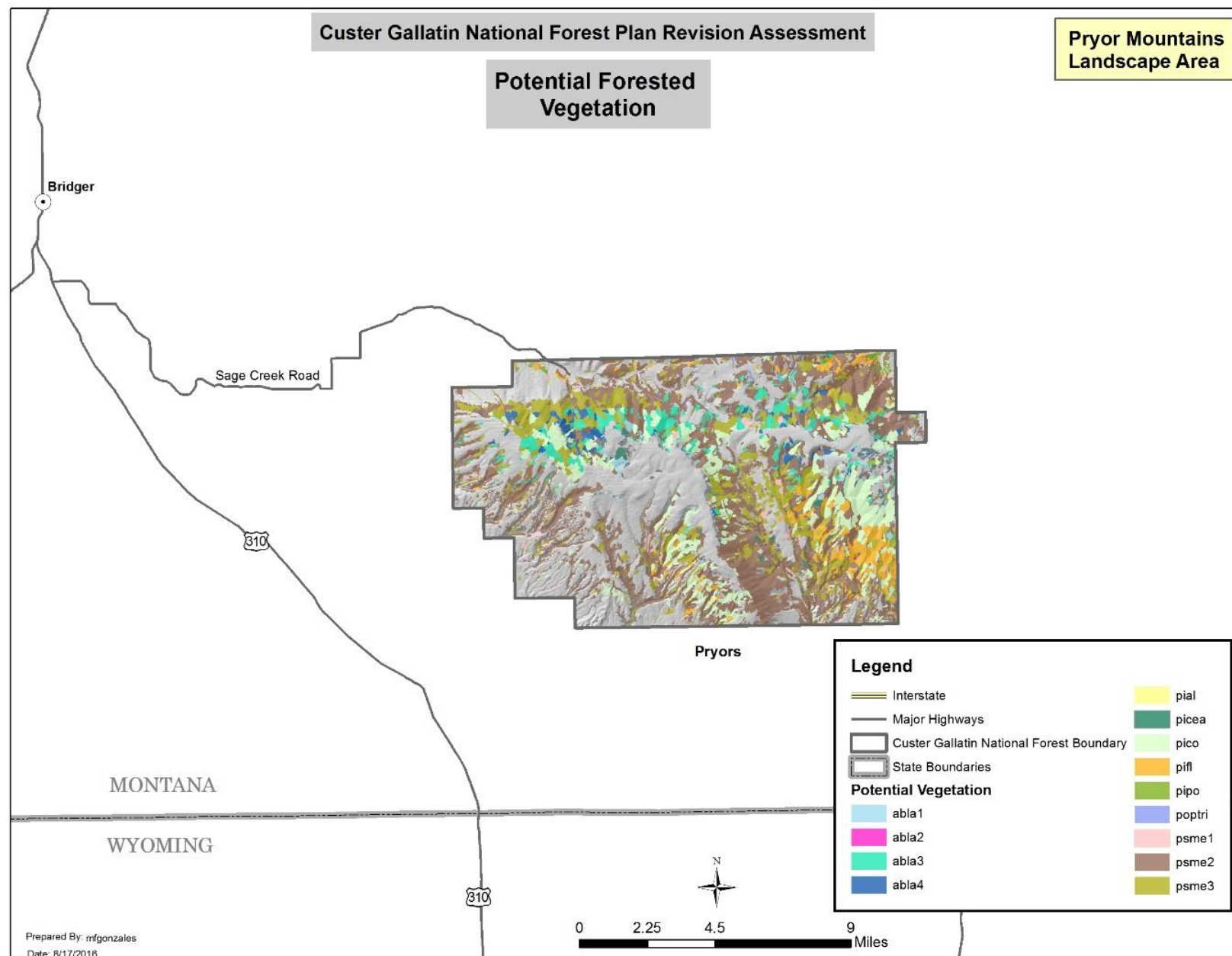


Figure 109. Potential forested vegetation for the Pryors analysis area, VMap – Jones PVT

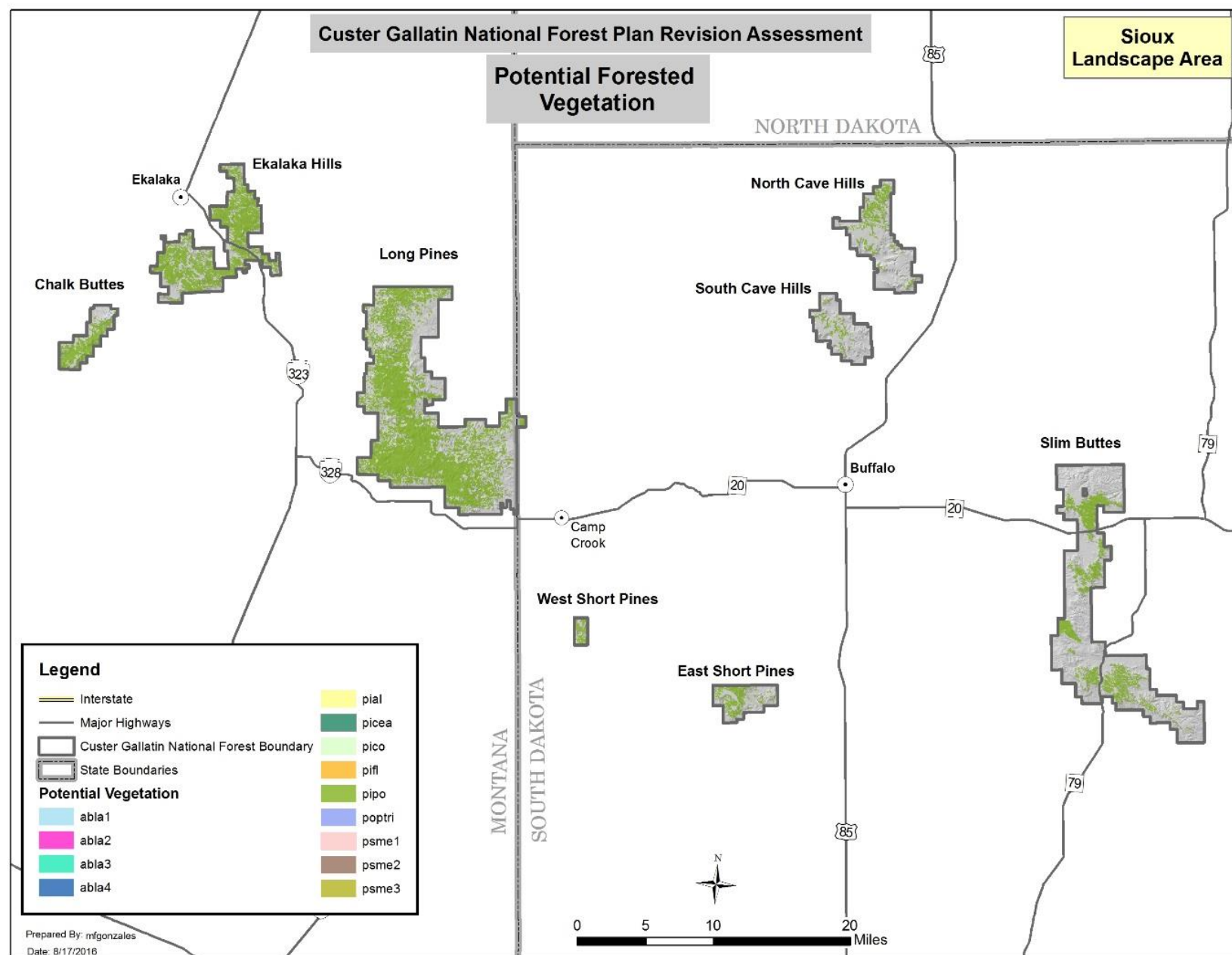


Figure 110. Potential forested vegetation for the Sioux analysis area, VMap – Jones PVT



*Custer Gallatin National Forest Assessment – Forested Terrestrial Vegetation*

**Table 60. Proportion of tree species presence and TPA by size class by analysis area and ecological unit, R1 Summary Database, FIA plots**

Species/ Size Class	Ashland		Bridgers Bangtails Crazies		Madison, Henrys Lake, Gallatin, Absaroka and Beartooth Mtns		Pryors		Sioux			Montane		Pine Savanna	
	TPA	% Area	TPA	% Area	TPA	% Area	TPA	% Area	TPA	% Area		TPA	% Area	TPA	% Area
ABLA															
0 - 4.9"	0	0.00%	1108.35	38.98 %	960.75	33.63 %	173	13.46 %	0	0.00%		945.64	33.37 %	0	0.00%
5 - 9.9"	0	0.00%	25.69	31.72 %	19.83	28.10 %	10.65	15.39 %	0	0.00%		20	27.96 %	0	0.00%
10 - 14.9"	0		4.14		3.93		3.7		0			3.94		0	
15 - 19.9"	0		0.19		0.34		0.46		0			0.33		0	
20 - 24.9"	0		0.19		0		0		0			0.02		0	
25"+	0		0		0		0		0			0		0	
BEPE															
0 - 4.9"	0	0.00%	0	0.00%	2.26	0.08%	0	0.00%	0	0.00%		2	0.07%	0	0.00%
5 - 9.9"	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%		0	0.00%	0	0.00%
10 - 14.9"	0		0		0		0		0			0		0	
15 - 19.9"	0		0		0		0		0			0		0	
20 - 24.9"	0		0		0		0		0			0		0	
25"+	0		0		0		0		0			0		0	
FPRE															
0 - 4.9"	7.19	0.69%	0	0.00%	0	0.00%	0	0.00%	113.74	4.31%		0	0.00%	37.48	1.72%
5 - 9.9"	0	0.69%	0	0.00%	0	0.00%	0	0.00%	0.83	3.45%		0	0.00%	0.24	1.47%
10 - 14.9"	0.16		0		0		0		0.21			0		0.18	
15 - 19.9"	0		0		0		0		0.21			0		0.06	
20 - 24.9"	0		0		0		0		0			0		0	

*Custer Gallatin National Forest Assessment – Forested Terrestrial Vegetation*

Species/ Size Class			Bridgers Bangtails Crazies		Madison, Henrys Lake, Gallatin, Absaroka and Beartooth Mtns										
	Ashland						Pryors		Sioux			Montane		Pine Savanna	
	TPA	% Area	TPA	% Area	TPA	% Area	TPA	% Area	TPA	% Area		TPA	% Area	TPA	% Area
25"+	0.08		0		0		0		0			0		0.06	
JUNIP															
0 - 4.9"	34.9 2	5.14%	2.42	0.81%	7.89	0.88%	0	0.00%	2.59	0.86%		7.16	0.84%	25.72	3.92%
5 - 9.9"	7.83	10.27 %	0.58	1.61%	1.32	2.13%	1.39	9.62%	0	0.00%		1.26	2.35%	5.6	7.35%
10 - 14.9"	1.73		0.19		0.13		0.46		0		0.15	1.24			
15 - 19.9"	0.33		0		0		1.39		0		0.05	0.24			
20 - 24.9"	0.08		0		0		0.46		0		0.02	0.06			
25"+	0.08		0		0		0		0		0	0			
PIAL															
0 - 4.9"	0	0.00%	72.55	6.45%	141.9 9	10.93 %	0	0.00%	0	0.00%		131.3 3	10.18 %	0	0.00%
5 - 9.9"	0	0.00%	35.52	13.71 %	13.3	15.40 %	0	0.00%	0	0.00%		14.68	14.73 %	0	0.00%
10 - 14.9"	0		2.52		5.79		0		0		5.32	0			
15 - 19.9"	0		0		1.73		0		0		1.52	0			
20 - 24.9"	0		0		0.29		0		0		0.26	0			
25"+	0		0		0.01		0		0		0.01	0			
PICO															
0 - 4.9"	0	0.00%	115.61	8.87%	154.7 2	13.52 %	57.6 7	3.85%	0	0.00%		148.1 2	12.80 %	0	0.00%
5 - 9.9"	0	0.00%	48.83	28.39 %	32.81	25.45 %	5.55	5.77%	0	0.00%		33.19	25.01 %	0	0.00%
10 - 14.9"	0		8.67		8.47		3.24		0		8.3	0			
15 - 19.9"	0		0.92		0.87		0.46		0		0.86	0			
20 - 24.9"	0		0.4		0.05		0		0		0.08	0			
25"+	0		0.05		0		0		0		0	0			
PIEN															

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Species/ Size Class			Bridgers Bangtails Crazies		Madison, Henrys Lake, Gallatin, Absaroka and Beartooth Mtns										
	Ashland						Pryors		Sioux			Montane		Pine Savanna	
	TPA	% Area	TPA	% Area	TPA	% Area	TPA	% Area	TPA	% Area		TPA	% Area	TPA	% Area
0 - 4.9"	0	0.00%	188.62	16.94 %	154.54	16.95 %	0	0.00%	0	0.00%		152	16.36 %	0	0.00%
5 - 9.9"	0	0.00%	11.65	24.19 %	11.76	26.73 %	0	3.85%	0	0.00%		11.34	25.72 %	0	0.00%
10 - 14.9"	0		3.69		5.37		0.46		0		5.06	0			
15 - 19.9"	0		0.58		2.41		0.93		0		2.21	0			
20 - 24.9"	0		0		0.6		0.93		0		0.56	0			
25"+	0		0.58		0.28		0.46		0		0.32	0			
PIFL2															
0 - 4.9"	0	0.00%	32.24	5.91%	23.48	3.16%	46.13	7.69%	0	0.00%		24.99	3.55%	0	0.00%
5 - 9.9"	0	0.00%	2.33	3.23%	1.74	3.85%	10.18	21.15 %	0	0.00%		2.08	4.40%	0	0.00%
10 - 14.9"	0		1.55		0.54		4.63		0		0.76	0			
15 - 19.9"	0		0		0.05		0		0		0.05	0			
20 - 24.9"	0		0		0		0		0		0	0			
25"+	0		0		0		0		0		0	0			
PIPO															
0 - 4.9"	132.9	13.77 %	0	0.00%	0	0.00%	0	0.00%	235.24	13.79 %		0	0.00%	161.99	13.78 %
5 - 9.9"	16.64	30.87 %	0	0.00%	0.24	0.38%	0	0.00%	11.21	26.72 %		0.21	0.33%	15.1	29.69 %
10 - 14.9"	7.89		0		0.2		0		5.81		0.18	7.3			
15 - 19.9"	2.04		0		0.04		0		3.32		0.03	2.41			
20 - 24.9"	0.37		0		0		0		0.42		0	0.39			
25"+	0.08		0		0		0		0		0	0.06			
POPUL															
0 - 4.9"	0	0.00%	0	0.00%	13.14	0.15%	0	0.00%	0	0.00%		11.59	0.13%	0	0.00%

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Species/ Size Class	Ashland		Bridgers Bangtails Crazies		Madison, Henrys Lake, Gallatin, Absaroka and Beartooth Mtns		Pryors		Sioux			Montane		Pine Savanna	
	TPA	% Area	TPA	% Area	TPA	% Area	TPA	% Area	TPA	% Area		TPA	% Area	TPA	% Area
5 - 9.9"	0	0.00%	0	0.00%	0.02	0.08%	0	0.00%	0	0.00%		0.02	0.07%	0	0.00%
10 - 14.9"	0		0		0		0		0						
15 - 19.9"	0		0		0		0		0						
20 - 24.9"	0		0		0		0		0						
25"+	0		0		0		0		0						
POTR5															
0 - 4.9"	0	0.00%	5.81	0.65%	40.77	1.36%	40.37	3.85%	15.51	0.86%		37.86	1.39%	4.41	0.25%
5 - 9.9"	0	0.00%	0	0.00%	0.4	0.57%	1.85	3.85%	0	0.00%		0.42	0.64%	0	0.00%
10 - 14.9"	0		0		0.1		0.46		0		0.1	0			
15 - 19.9"	0		0		0		0		0		0	0			
20 - 24.9"	0		0		0		0		0		0	0			
25"+	0		0		0		0		0		0	0		0	
PSME															
0 - 4.9"	0	0.00%	278.9	18.01 %	129.58	9.73%	63.44	12.69 %	0	0.00%		139.63	10.52 %	0	0.00%
5 - 9.9"	0	0.00%	16.57	33.55 %	11.25	20.15 %	5.56	20.39 %	0	0.00%		11.5	21.27 %	0	0.00%
10 - 14.9"	0		5.92		6.26		4.32		0		6.17	0			
15 - 19.9"	0		3.38		2.59		3.1		0		2.68	0			
20 - 24.9"	0		1.55		0.79		0.73		0		0.85	0			
25"+	0		0.42		0.27		0.14		0		0.28	0			

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**Table 61. Treatment activity acres by decade by analysis area, FACTS**

	Madison, Henrys Lake, Gallatin, Absaroka and Beartooth Mtns			Bridgers, Bangtails, Crazyes			Pryors			Ashland			Sioux		
Year Period	Harvest	Fuels	TSI/ Refo	Harvest	Fuels	TSI/Refo	Harvest	Fuels	TSI/ Refo	Harvest	Fuels	TSI/ Refo	Harvest	Fuels	TSI/ Refo
1940-1949	1453	142	97												10
1950-1959	7197	2731	1244	1654	214					1782	0	0	0	0	17
1960-1969	26380	22814	10961	7103	3062	823	273	143		0	0	63	3563	4080	676
1970-1979	18701	24600	14732	3805	4164	2552	138	186	143	250	210	892	1895	2532	860
1980-1986	15886	27090	25859	3563	3516	2753	179	423	460	1143	2172	1495	2234	4649	1146
1987-1989	7769	10641	8872	2196	2383	1268	271	735	7	2930	4729	1425	1218	1906	961
1990-1999	18464	42166	18017	5760	5361	3928	27	941	970.3	1978	16095	4367	3155	9610	11413
2000-2009	2951	23606.1	16456	148	2630	5256	13	19		2156	15748	3662	4388	8135	4915
2010-2015	3619.3	14386.6	16711.7	472	1552.4	0		0		239	15177.1	5228.5	550	4211	7098
Total	102420.3	168176.7	112949.7	24701	22882.4	16580	901	2447	1580.3	10478	54131.1	17132.5	17003	35123	27096
Unit Total	383546.7			64163.4			4928.3			81741.6			79222		

**Table 62. Acres of R1 Habitat Type Group by Jones PVT by SIMPPLLE Habitat Type Group by analysis area, VMap**

R1 Broad PVT	R1 Habitat Type Group	Acres	Jones PVT	Acres	SIMPPLLE HTG	Acres
Ashland						
Warm Dry	Warm Dry	232688	pipo	232688	A2	232688
Sioux						
Warm Dry	Warm Dry	72014	pipo	72014	A2	72014
Pine savanna						
	Warm Dry	304702	pipo	304702	A2	304702
Bridger Bangtail Crazies						
Warm Dry	Hot Dry	255	pifl	255	A1	255
	Warm Dry	735	pipo	4	A2	735
			psme1	731		
	Mod Warm Dry	103245	psme2	96852	B2	96852
			psme3	6393	B1	6393
Cool Moist	Cool Moist	10005	picea	3949	D2	3949
			abla2	6056	D3	6056
	Cool Wet	19257	abla1	19257	E2	19257
	Cool Mod Dry to Moist	80447	pico	7632	F1	7632
			abla3	72815	F2	72815
Cold	Cold	5155	abla4	5155	G1	5155
	Cold Timberline	3939	pial	3939	G2	3939
Madison, Henrys Lake, Gallatin, Absaroka and Beartooth Mtns						
Warm Dry	Hot Dry	8252	pifl	8252	A1	8252
	Warm Dry	14080	pipo	673	A2	14080
			psme1	13406		
	Mod Warm Dry	336909	psme2	292875	B2	292875
			psme3	44034	B1	44034
Cool Moist	Cool Moist	158222	picea	49993	D2	49993
			abla2	108229	D3	108229
	Cool Wet	100552	abla1	100552	E2	100552
	Cool Mod Dry to Moist	587642	pico	72001	F1	72001
			abla3	515641	F2	515641
Cold	Cold	149328	abla4	149328	G1	149328
	Cold Timberline	255940	pial	255940	G2	255940
Pryor						
Warm Dry	Hot Dry	2827	pifl	2827	A1	2827
	Warm Dry	988	pipo	345	A2	988
			psme1	642		
	Mod Warm Dry	29555	psme2	21453	B2	21453
			psme3	8102	B1	8102
Cool Moist	Cool Moist	656	picea	656	D2	656
			abla2	0	D3	0

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R1 Broad PVT	R1 Habitat Type Group	Acres	Jones PVT	Acres	SIMPPLLE HTG	Acres
	Cool Wet	761	abla1	761	E2	761
	Cool Mod Dry to Moist	10124	pico	7200	F1	7200
			abla3	2924	F2	2924
Cold	Cold	1053	abla4	1053	G1	1053
	Cold Timberline	54	pial	54	G2	54
Montane						
Warm Dry	Hot Dry	11334	pifl	11334	A1	11334
	Warm Dry	15803	pipo	1022	A2	15803
			psme1	14779		0
	Mod Warm Dry	469709	psme2	411180	B2	411180
			psme3	58529	B1	58529
Cool Moist	Cool Moist	168883	picea	54598	D2	54598
			abla2	114285	D3	114285
	Cool Wet	120570	abla1	120570	E2	120570
	Cool Mod Dry to Moist	678213	pico	86833	F1	86833
			abla3	591380	F2	591380
Cold	Cold	155536	abla4	155536	G1	155536
	Cold Timberline	259933	pial	259933	G2	259933

**Table 63. Transitional forest patch size by analysis area by Habitat Type Group by PVT, VMap**

Transitional Forest by Landscape Area	R1 Habitat Type Group	PVT	Sum Acreage	No. of Patches	Average Size	Maximum Size	Min Size
Ashland	Warm Dry	pipo	82126	2059	40	6651	<1
Bridgers, Bangtails, Crazies	Cool Wet	abla1	104	21	5	14	1
	Cool Moist	abla2	58	6	10	29	1
		picea	47	6	8	13	4
	Cool Mod Dry to Moist	abla3	1498	103	15	378	<1
	Cold	abla4	88	12	7	17	2
	Cold Timberline	pial	112	10	11	52	2
	Mod Warm Dry	psme2	1446	148	10	229	<1
Madison, Henrys Lake, Gallatin, Absaroka and Beartooth Mtns	Cool Wet	abla1	7458	590	13	568	<1
	Cool Moist	abla2	9817	449	22	3246	<1
		picea	3427	273	13	144	<1
	Cool Mod Dry to Moist	abla3	50135	2007	25	3419	<1
		pico	3090	40	77	2600	<1
	Cold	abla4	15300	726	21	1399	<1
	Cold Timberline	pial	8751	417	21	544	<1
	Hot Dry	pifl	393	45	9	38	<1
	Warm Dry	pipo	134	17	8	29	2

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Transitional Forest by Landscape Area	R1 Habitat Type Group	PVT	Sum Acreage	No. of Patches	Average Size	Maximum Size	Min Size
	Mod Warm Dry	psme1	4458	313	14	239	<1
		psme2	73680	2134	35	16279	<1
		psme3	3862	346	11	365	<1
Pryors	Cool Moist	picea	78	6	13	23	3
	Hot Dry	pifl	7	2	4	6	1
	Warm Dry	psme1	5	2	3	3	3
	Mod Warm Dry	psme2	2522	20	126	2292	<1
		psme3	323	19	17	65	1
Sioux	Warm Dry	pipo	33293	987	34	16730	<1

**Table 64. Seedling and sapling patch size by analysis area by Habitat Type Group by PVT, VMap**

0-4.9 Tree Size by Landscape Area	R1 Habitat Type Group	PVT	Sum Acreage	No. of Patches	Average Size	Maximum Size	Min Size
Ashland	Warm Dry	pipo	1384	270	5	17	<1
Bridgers, Bangtails, Crazies	Cool Wet	abla1	584	96	6	18	1
	Cool Moist	abla2	152	19	8	31	2
		picea	15	4	4	7	1
	Cool Mod Dry to Moist	abla3	2778	281	10	64	<1
		pico	951	126	8	88	<1
	Cold	abla4	67	12	6	14	1
	Cold Timberline	pial	41	12	3	13	<1
	Hot Dry	pifl	5	3	2	2	1
	Warm Dry	pipo	3	1	3	3	3
		psme1	3	2	1	2	<1
	Mod Warm Dry	psme2	2543	339	8	50	<1
		psme3	194	32	6	18	2
Madison, Henrys Lake, Gallatin, Absaroka and Beartooth Mtns	Cool Wet	abla1	3605	452	8	59	<1
	Cool Moist	abla2	4269	385	11	123	1
		picea	1640	183	9	77	<1
	Cool Mod Dry to Moist	abla3	26676	1695	16	893	<1
		pico	8511	680	13	227	<1
	Cold	abla4	3870	340	11	134	<1
	Cold Timberline	pial	5801	1109	5	109	<1
	Hot Dry	pifl	451	46	10	66	1
	Warm Dry	pipo	7	2	4	7	1
		psme1	290	45	6	31	1
	Mod Warm Dry	psme2	8058	982	8	189	<1
		psme3	2000	189	11	107	<1
Pryors	Cool Mod Dry to Moist	pico	83	14	6	21	1



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<b>0-4.9 Tree Size by Landscape Area</b>	<b>R1 Habitat Type Group</b>	<b>PVT</b>	<b>Sum Acreage</b>	<b>No. of Patches</b>	<b>Average Size</b>	<b>Maximum Size</b>	<b>Min Size</b>
	Hot Dry	pifl	51	11	5	11	1
	Warm Dry	psme1	5	1	5	5	5
	Mod Warm Dry	psme2	191	32	6	24	<1
		psme3	87	18	5	9	<1
Sioux	Warm Dry	pipo	66	18	4	8	<1